PB87-180550

Development and Evaluation of a Real-Time pH and Conductivity Rain Monitor

Northrop Services, Inc.
Research Triangle Park, NC

Prepared for

Environmental Monitoring Systems Lab.
Research Triangle Park, NC

Apr 87

U.S. Department of Commerce
National Technical Information Service
NTIS

PB87-180550

EPA/600/4-87/010
April 1987

Development and Evaluation of a Real-Time pH and Conductivity Rain Monitor

by

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Contract Number EPA-68-02-4033

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TECHNICAL REPORT DATA
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1. REPORT NO. EPA/600/4-87/010	**2.**	**3. RECIPIENT'S ACCESSION NO.** PB87 180550/AS
4. TITLE AND SUBTITLE DEVELOPMENT AND EVALUATION OF A REAL-TIME pH AND CONDUCTIVITY RAIN MONITOR		**5. REPORT DATE** April 1987 **6. PERFORMING ORGANIZATION CODE**
7. AUTHOR(S) Richard J. Paur		**8. PERFORMING ORGANIZATION REPORT NO.**
9. PERFORMING ORGANIZATION NAME AND ADDRESS Northrop Services, Inc. Research Triangle Park, NC 27709		**10. PROGRAM ELEMENT NO.** **11. CONTRACT/GRANT NO.** 68-02-4033
12. SPONSORING AGENCY NAME AND ADDRESS U. S. Environmental Protection Agency Environmental Monitoring Systems Laboratory/RTP Methods Development & Analysis Division, MDB/MMS Research Triangle Park, NC 27711		**13. TYPE OF REPORT AND PERIOD COVERED** Final 1984-1986 **14. SPONSORING AGENCY CODE** EPA/600/09
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

Acidic wet deposition (acid rain) is thought to be responsible for a variety of deleterious effects on ecosystems and on natural and man-made materials. Determining and quantitating these effects is complicated by the fact that rain is a low ionic strength solution of many different salts and organic compounds. Measurements of parameters such as pH are difficult and the rain samples are subject to modification by chemical and biological mechanisms. Detailed understanding of a rain event requires measurement of concentration of chemical species as a function of amount of precipitation during a rain event because rain is much more concentrated at the beginning of an event and becomes more dilute as the various salts are washed out of the atmosphere.

This report describes the features and performance of a monitor that was designed to fractionate a rain event into samples corresponding to 0.3 mm of rain, determine the pH and conductivity of the samples within approximately one minute of collection, and store the remainder of the sample for more detailed analysis.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT RELEASE TO PUBLIC	**19. SECURITY CLASS** *(This Report)* UNCLASSIFIED	**21. NO. OF PAGES** 141
	20. SECURITY CLASS *(This page)* UNCLASSIFIED	**22. PRICE**

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

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FOREWORD

Measurement and monitoring research efforts are designed to anticipate environmental problems, to support regulatory actions by developing an in-depth understanding of the nature and processes that impact health and the ecology, to provide innovative means of monitoring compliance with regulations, and to evaluate the effectiveness of health and environmental protection efforts through the monitoring of long-term trends. The Environmental Monitoring Systems Laboratory, Research Triangle Park, NC, has responsibility for: assessment of environmental monitoring technology and systems for air, implementation of agency-wide quality assurance programs for air pollution measurement systems, and supplying technical support to other groups in the agency including the EPA component of the National Acid Precipitation Assessment Program (NAPAP).

A portion of EMSL's support of NAPAP involves review of precipitation monitoring methodology, and contributions to such methodology by providing improved QA or expanded measurement capability. The monitor development program described in this report provides a measure of QA support by making unattended field pH and conductivity measurement in near real-time. Fractionation of the rain event into small intervals and storing the resulting aliquot under refrigeration for detailed subsequent analysis provides more complete information about the way in which materials are washed out of the atmosphere by rainfall.

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ABSTRACT

Acidic wet deposition (acid rain) is thought to be responsible for a variety of deleterious effects on ecosystems and on natural and man-made materials. Determining and quantitating these effects is complicated by the fact that rain is a low ionic strength solution of many different salts and organic compounds. Measurements of parameters such as pH are difficult and the rain samples are subject to modification by chemical and biological mechanisms. Detailed understanding of a rain event requires measurement of concentration of chemical species as a funciton of amount of precipitation during a rain event because rain is much more concentrated at the beginning of an event and becomes more dilute as the various salts are washed out of the atmosphere.

This report describes the features and performance of a monitor that was designed to fractionate a rain event into samples corresponding to 0.3 mm of rain, determine the pH and conductivity of the samples within approximately one minute of collection, and store the remainder of the sample for more detailed analysis.

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Introduction

The main objectives of this project have been to design, construct and evaluate an automated wet precipitation monitor that can measure the pH and conductivity of rain in near real-time, collect discrete fractions of rain events, and store the samples for later laboratory analysis. The design of the monitor called for unattended operation for periods of up to one week. Evaluation of the system included studies of the stability of rain samples under the refrigerated storage conditions provided by the sampler.

To achieve the primary objectives a monitor (see Figure 1 for schematic of unit) with the following key features was designed, fabricated and tested:

The monitor utilized a Teflon-coated inlet. The rain was collected in dual accumulators so that one sample could be undergoing analysis while the succeeding sample was being collected in the other accumulator. This arrangement allowed near real-time measurements, since a sample corresponds to 0.3 mm of rain and is analyzed as soon as that increment of rain is accumulated (about 45 seconds during a 1-inch per hour rainfall).

A microprocessor (Z80) was used to control the pH and conductivity measurements and the storage carousel. The microprocessor also controlled a QC program and produced a printed record of the QC results. The system allowed operator specification of the frequency of QC analysis and a number of measurement parameters, such as the tolerance band for successive pH readings, before accepting a series of readings as a valid pH measurement. An additional option that was not implemented in the original sampler was use of the microprocessor to telemeter data back to the laboratory.

Thirty-five milliliter aliquots of the samples were stored in a refriger-

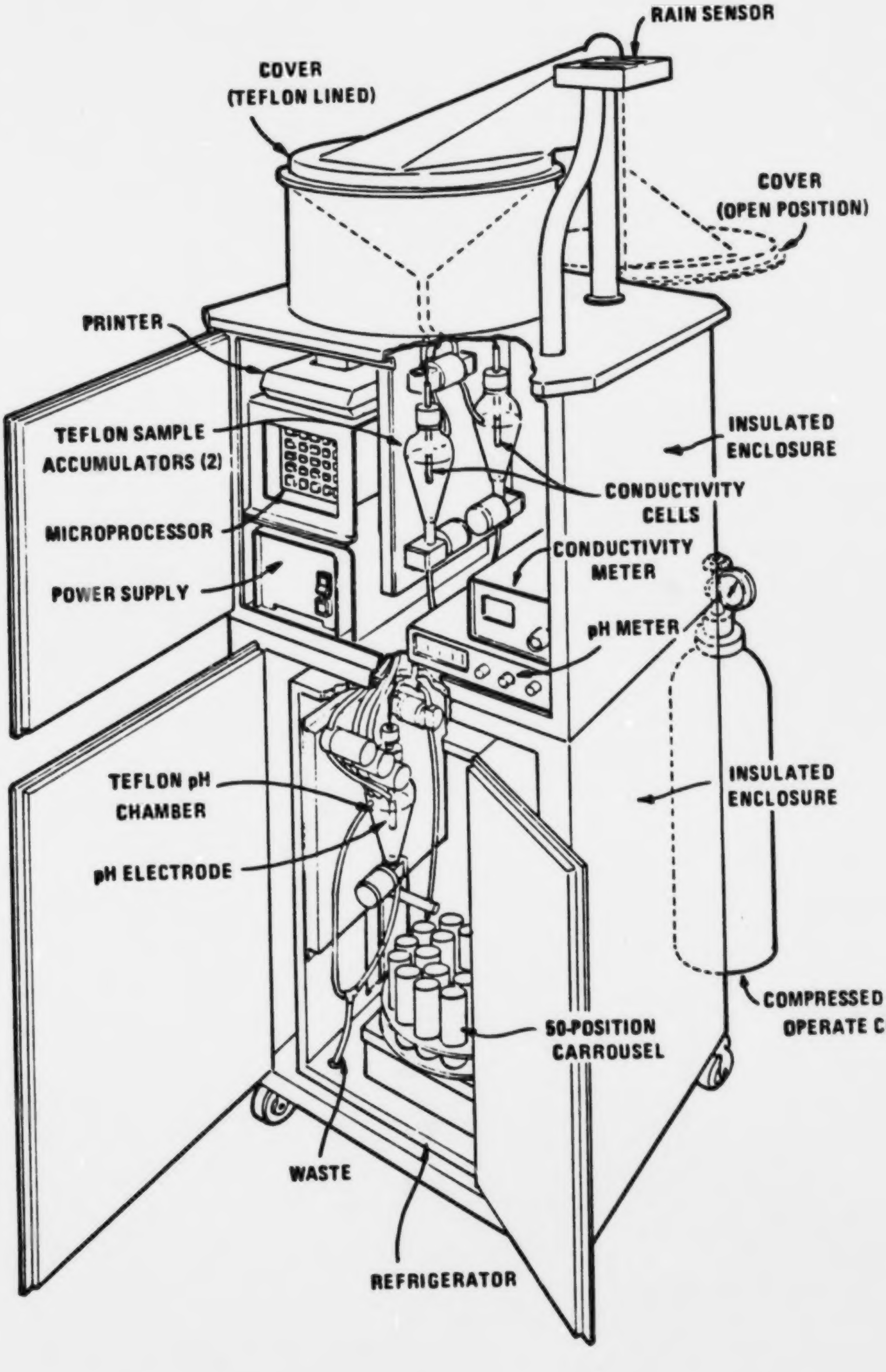
RAIN SENSOR
COVER (TEFLON LINED)
COVER (OPEN POSITION)
PRINTER
TEFLON SAMPLE ACCUMULATORS (2)
MICROPROCESSOR
POWER SUPPLY
INSULATED ENCLOSURE
CONDUCTIVITY CELLS
CONDUCTIVITY METER
pH METER
TEFLON pH CHAMBER
pH ELECTRODE
INSULATED ENCLOSURE
COMPRESSED AIR TO OPERATE COVER
50-POSITION CARROUSEL
WASTE
REFRIGERATOR

Figure 1. EPA automated rain sampler.

ated carousel for more extensive analysis in a laboratory.

Thus, the output from the sampler consists of a printed record of analyses of QC samples, of the time, date, vial number, pH and conductivity of rain samples, and up to fifty 35 ml aliquots of rain.

This report contains some examples of typical rain events described in terms of ionic concentrations vs vial number (equivalent to amount of rain) and presents the results of sample stability studies in addition to providing conclusions and recommendations regarding the performance of the sampler. Appendix A of the report is a copy of the "Acid Precipitaiton Monitor Manual" which was written by Northrop Services, Inc. to describe the monitor and its operation.

This project was carried out in a cooperative effort between the Methods Development Branch of the Environmental Monitoring Systems Laboratory and the Inorganic Pollutant Analysis Branch of the Atmospheric Sciences Research Laboratory. Dr. Richard Paur of EMSL was the project officer and Mr. Ralph Baumgardner and Mr. Robert K. Stevens of ASRL were the technical monitors. The work was carried out under contract 68-02-4033 with Northrop Services, Inc. Dr. William Ellenson was the NSI project leader. Mr. Keith Kronmiller was responsible for the electronic design and fabrication and the microprocessor code. Mr. Warren Daniels was responsible for the mechanical fabrication.

Conclusions

The objectives of the program have been accomplished. The sampler can reliably measure the pH and conductivity of rain aliquots representing small fractions of a rain event and provides systematic QC information that can be used to support the validity of the measurements or to alert the operator to problems with the monitor.

A detailed manual (describing the hardware and software in sufficient detail to allow duplication by knowledgeable readers) has been produced.

Sample stability does not appear to pose serious problems, although these results are quite limited.

Hardware problems, such as sticking solenoid values, have been overcome in a systematic fashion and the monitor appears to be quite reliable in terms of general mechanical and electrical function.

Laboratory evaluations and a field evaluation program during which approximately 40 rain events (approximately 900 vials of rain) were measured led to the following conclusions:

1. The automatic QC program consists of determining the pH of a QC solution at preset intervals (typically twice a day). During normal operation the pH determinations are stable to within ± 0.05 pH units of the expected value.
2. The pH determinations during rain events agree with laboratory pH determinations to within about 0.05 pH units for pH values of less than 4.5. Higher pH samples, with correspondingly lower ionic strengths, are more difficult to measure and differences between the automated monitor and the laboratory determinations may increase to as much as 0.2-0.3 pH units.

3. The estimates of conductivity of rain samples typically agree within ± 15 percent with laboratory measurements. Larger deviations are occasionally observed early in rain events. These deviations are consistent with the hypothesis that the first few samples may contain incompletely dissolved particulate which has been washed out of the atmosphere. Such particulate matter may not have time to dissolve before the conductivity measurements are made by the automated sampler; however, the particulate may be more completely dissolved before the laboratory measurements are carried out.

4. The monitor design is such that each sample is quite thoroughly drained from the system following analysis. Little material remains to mix with the succeeding sample. This aspect of sampler performance was tested by introducing a high concentration test solution into the sampler and following it with a series of deionized water samples. The first sample of deionized water contained 8 percent of the ions present in the concentrated test solution. The second sample of deionized water contained about 2 percent of the ions in the concentrated solution, and subsequent samples did not show measurable amounts of ions from the test solution.

5. Limited tests of stability of NH_4^+, $SO_4^=$, NO_3^-, Cl^-, conductivity and pH in performance solutions and in 50/50 mixtures of rain from an Aerochem Metrics bulk sample and a performance solution are inconclusive but show generally decreasing amounts of NH_4^+ and NO_3^- ion but increasing conductivity and H^+ (decrease in pH). The samples show less degradation than had been expected. Surprisingly, the solution containing natural rain (and presumably some biological activity) shows less change in ionic concentrations that the solution which consisted only of the performance solution. As expected, samples stored at

room temperature and exposed to light showed larger changes than samples stored in (dark) refrigerators.

6. One of the primary problems to be resolved in design and use of a sampler such as the one developed under this project is the problem of sizing the inlet. The inlet must be large enough to collect sufficient rain during light rains and small enough to prevent system 'overload' during heavy rains. The 18-inch diameter inlet used on the current monitor is too large; it will generate 3000 vials (samples) during a 30-inch rainfall season.

Recommendations

1. The current project did not have sufficient resources to address organic compounds in rain. No information regarding sample integrity for organic acids, pesticides, or other organic species was obtained. The performance of the sampler with respect to these materials should be investigated so that the behavior of these materials in rain could be measured.

2. As noted in the Conclusions, the inlet opening was too large for many applications. It is estimated that an opening that is a factor of 2 to 3 smaller than the current one would be a better choice. However, the large inlet does provide a fine fractionation of a rain event and can produce detailed information on washout phenomena.

3. A conductivity bridge with higher conductivity ranges should be incorporated into future units. The current model had an upper limit of 100 microsiemens, but that range was often exceeded during the early portions of a rain event.

4. The current monitor is limited to a lower operating temperature of approximately 15°F. For routine field operations the monitor should have heaters and insulation added to permit cycling to lower temperatures.

Acknowledgements

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General Design Features

A detailed description of the design of the monitor is presented in Appendix A. This section is intended to provide a brief summary of the design to facilitate understanding the results section and to indicate some of the considerations that have gone into the design.

1. A Z-80 based microprocessor system controls all operations of the monitor. The microprocessor technology allows measurements to be made in near real-time and provides the flexibility that is needed to allow varied applications. The control code for the microprocessor is contained in an Electronically Programmed Read Only Memory (EPROM) chip so that operation is automatically initiated at power-up of the monitor. Modifications to the operating code are implemented routinely with a software development system that leads to the creation of new EPROMs. The unit contains a real-time clock with battery backup; this, plus the automatic program initiation at power-up, means that the unit can recover from power outages with no problems of startup and/or continuing operation. The conductivity meter output is transferred to the microprocessor system through an eight-bit A/D system; the pH meter is read via a parallel interface.

The microprocessor software includes routines for automatic measurement of a quality control solution at programmed intervals, the use of a pH 'Exit Time' which is the maximum time that the microprocessor will wait for a stable pH reading, and use of a 'Delta pH' variable that defines the width of the pH tolerance band that is used as the criteria for a stable pH reading.

2. The output from the microprocessor is sent to an Alps Corporation printer which provides the hard copy record. The output could also be sent to a telemetry interface so that the monitor's results could be obtained at some

convenient location; this has not been done with the current unit.

3. The operator communicates with the microprocessor via a sixteen-key keypad and a liquid crystal display unit. Variables such as time, date, vial position, QC intervals, etc. can easily be queried and altered.

4. The rain-sensing and open/close mechanism was obtained from S. Krupa (University of Minnesota). This mechanism is air-driven, since it was originally designed for use in a very low (electrical) power sampler. However, an electrically powered open/close mechanism is feasible if sufficient power is available.

5. The monitor uses dual accumulators; this arrangement allows a second sample to be collected and processed while an earlier sample is still being analyzed for pH. The conductivity electrodes are placed in the accumulators; use of two conductivity probes led to some initial differences between the conductivity values obtained by the two probes. Switching to gold-coated probes has eliminated this problem.

6. The monitor uses an Orion pH meter and electrode. The electrode is stored in KCl solution when the monitor is not actively monitoring rain or QC solutions. The electrodes have satisfactory reliability, although they exhibit considerable variability in lifetime.

Results of Hardware Evaluation

A significant portion of the monitor evaluation involved the suitability of a number of components and subsystems incorporated into the monitor. Table 1 presents an overall summary of this evaluation on a component-by-component basis. Some improvements are suggested in the 'Recommendations' section of this report; however, the monitor was successful in achieving the objective of automated rain collection with real-time measurement of pH and conductivity.

Table 1. Precipitation Monitor Component Evaluation

Unit	Present In-Use	Advantage(A) and Disadvantages(D)
Rain Cover	Krupa, University of Minnesota	A: Large diameter cover collects small rain fractions (.01 in/vial) A: Teflon lined for sample stability D: Can only collect small total events because of 50 vial limitation A: Quite low power and compressed air consumption. D: One of a kind -- have been unable to obtain additional units A: Highly reliable in operation D: Relatively complicated construction
Rain Sensor	Aerochem Metrics	A: Standard component (used in most-common network sampler, so comparable) A: Sensitive to small quantities of rain A: Has heated surface to mini[illegible]ze condensation effects D: Requires minor rewi[illegible] use here
Electrode	Orion 90-0062	A: Research-grade el[illegible] with rapid equilibration A: Widely used in laboratories for low-ionic strength solutions D: Somewhat sensitive to clogging
pH meter	Orion 611	A: Top-of-the-line meter; temperature compensated D: Relatively expensive (~1K)
Conductivity cell and probe	Cole Parmer	A: Also used in the analysis lab A: Probe recommended by manufacturer for low ionic strength solutions D: Monitor design requires two matched electrodes D: Present monitor has built-in upper conductivity maximum of 100 μSiemens
Printer	ALPS	A: Has shown high reliability A: Relatively low-cost ($150)
Carousel	Eldex	A: Can handle 50 50-ml vials D: Not indexed in an absolute sense so that power outages present problems A: Demonstrated reasonable reliability

Table 1. Precipitation Monitor Component Evaluation (continued)

Unit	Present In-Use	Advantage(A) and Disadvantages(D)
Sample Vials	Fisher	A: No contamination or effect on rain sample integrity noted D: Require capping and labeling
Valves (pinch)	Angar	A: Reasonably simple design D: Non-Teflon tubing near valve (though no effects noted to date) D: Not widely available at this time D: Tubing requires periodic maintenance
Level Sensors	Wire-probe	D: Require sensitivity adjustment D: A few problems with false detection under high humidity conditions A: Operated reliably in general
Refrigerator	J. C. Penney	A: Convenient to procure D: Requires electrical modification for zero-level crossing of power
Housing	ASRL machine shop	A: Durable, well-constructed with summer cooling fans
Winter heating	Custom heat controls	D: Insufficient heating for temperatures below about 10 F
Software	Mostek Z-80 code	A: Documented reasonably well D: All coding is in machine language A: Demonstrated high versatility
Hardware	Mostek boards	A: Commercially available boards of high quality A: Demonstrated high reliability - no field or lab problems to date
Rain accumulators	Fisher	A: Transparent Teflon for visibility of operation D: Require mechanical modifications - design not optimized
QC provision	Laboratory prepared solution	A: Proven very valuable in evaluation of electrode response

Selected Results from Monitor Evaluation

Table 2 shows a comparison of the pH results between the field monitor and the laboratory analyses for samples collected during 20 rain events. The results that are presented here include all analyzed rain events since December, 1985, that had more than two samples collected by the rain monitor (corresponds to 0.02 inches of rain). Field monitor analyses were performed automatically at the time of collection (one sample vial for each 0.01 inch rain). Laboratory analyses were performed as soon as possible after the samples were collected from the precipitation monitor, usually within 24 hours. A value was calculated for each vial by subtracting the pH value found in the laboratory from the pH value found in the field, as reported on the printer output. These difference values were then averaged over all the samples of the rain event and a standard deviation was calculated. With the exception of several rain events, the agreement was quite satisfactory: agreement to within about 0.05 pH units. Larger deviations (0.2-0.3 pH units) were found for several events where there was quite low acidity (pH greater than 4.5 for all samples). These samples possessed low ionic strength which would lead to a more sluggish pH electrode response, especially at the reduced temperature used for the monitor measurements.

Figure 2 presents the results for the conductivity evaluation as a comparison between field monitor and laboratory analyses. The 1:1 line has been added to the figure for comparative purposes. The upper range limit of the conductivity meter of the monitor was 100.0 microsiemens; consequently, any data with exactly this reported value were not plotted because the actual conductivity may have been substantially higher. Overall, the agreement is

Table 2 pH Comparison for Field Monitor vs. Laboratory

Date of Event	# Vials Total in Event	# Vials Analyzed in Lab	Average Difference ± S.D.
12/12/85	7	5	.052 ± .031
12/13/85	49	19	.257 ± .122
01/03/86	10	4	.035 ± .072
01/19/86	36	15	.265 ± .597
01/25/86	12	9	.086 ± .051
02/10/86	28	20	.064 ± .059
03/13/86	49	17	.010 ± .120
03/14/86	43	22	.067 ± .114
03/19/86	50	5	.002 ± .064
03/27/86	27	27	.047 ± .038
04/07/86	10	8	-.010 ± .043
04/21/86	30	20	-.014 ± .034
04/26/86	50	18	-.034 ± .050
05/13/86	7	4	-.003 ± .043
05/20/86	50	20	-.042 ± .129
05/20/86	13	5	.046 ± .019
06/07/86	50	11	.011 ± .043
06/28/86	43	17	.055 ± .033
07/02/86	11	3	-.013 ± .116
07/10/86	37	10	-.006 ± .053

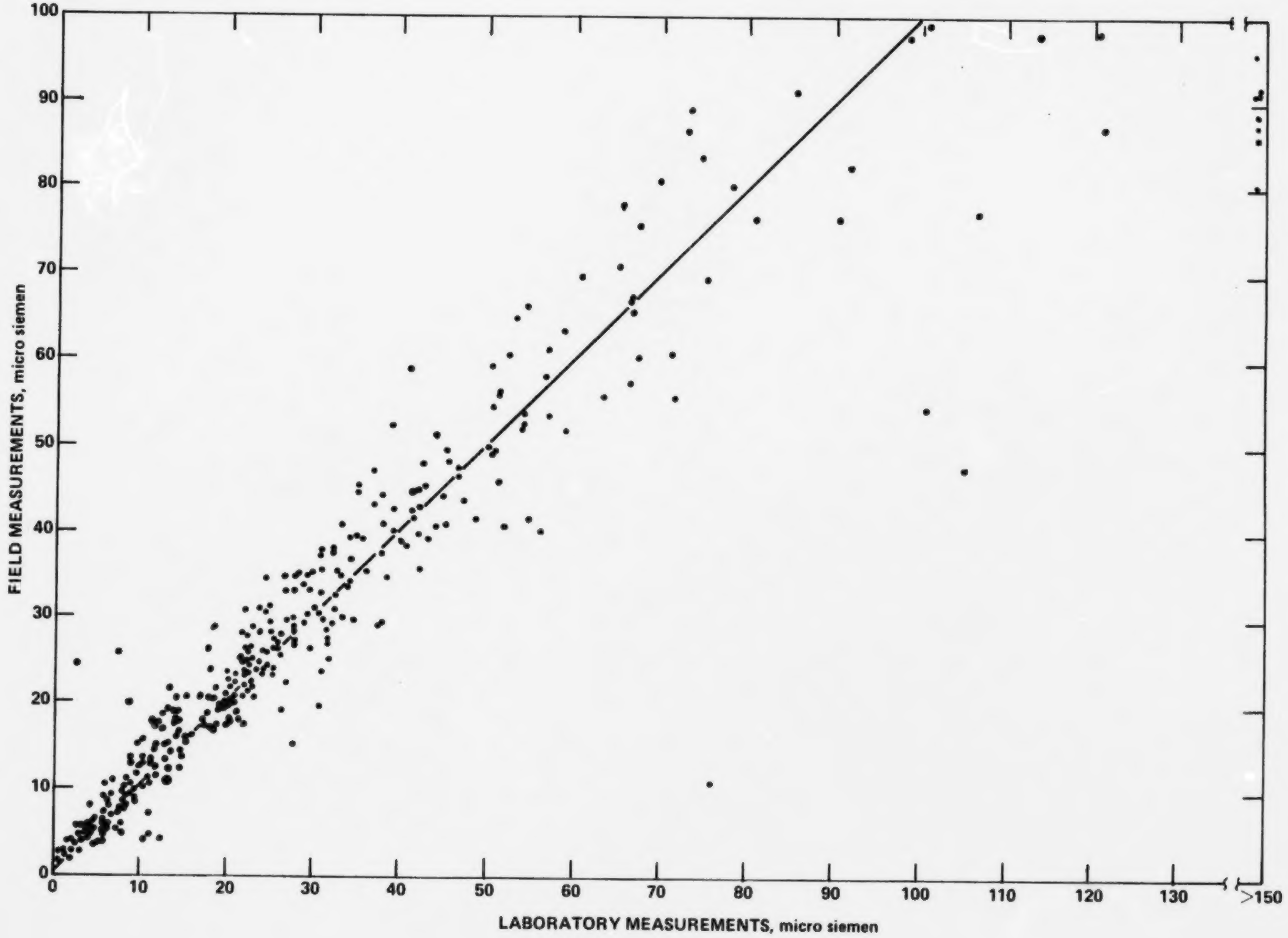


Figure 2. Comparison of field and laboratory conductivities on collected rain samples.

relatively good, to within about 15 percent in the middle of the scale and above. It should be noted that the differences represent the combined errors of the field and laboratory measurements. In about 2% of the cases, unusual differences were found. In some of the cases where the laboratory found values significantly greater than 100 microsiemens, (as high as 300 microsiemens in a few cases), a value less than 100 was reported by the field monitor. These instances were always associated with the very first vials of the given rain event. A plausible explanation is that coarse particles were being washed out but that it took a significant time for them to dissolve and release their ionic content to the collected rain water.

Figure 3 shows a selected typical segment of the plot of the daily quality control values that were produced by the monitor. At programmable intervals, the monitor automatically analyzed a quality control solution of 0.0001 normal sulfuric acid that had a nominal pH of 4.00. For the most part, the frequency of quality control checks varied from twice daily to four times daily during various portions of the evaluation. Hourly checks were sometimes made after major changes such as electrode replacement. As Figure 3 shows, the pH response was quite stable, within 0.05 pH units. This behavior generally typified the entire evaluation period. Rain events are indicated also on the figure. The break in the values around May 31 occurred after a power failure caused additional problems with the monitor leading to a short-term shutdown.

In March 1986, somewhat erratic deviations of the response, approximately 0.15 pH units, were noted. This problem was traced to the pH electrode which had become partially clogged and yielded a sluggish response. After cleaning of the electrode, the response returned to normal.

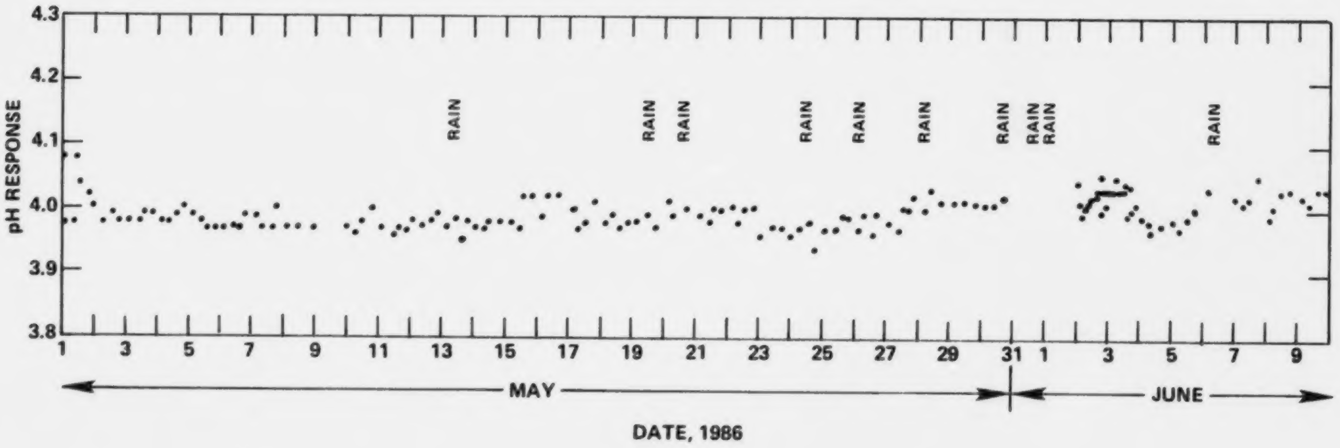


Figure 3. Plot of quality control results vs. date.

As an overall observation, the feature of having an automatic quality control sequence performs a very valuable function by greatly increasing confidence in the measurements. Early experience with rain measurements showed that pH electrode response could easily degrade in the field environment but that this would not be easily discerned through a simple inspection of the data. The use of a frequent quality control check allows such problems to be closely observed.

Very early attempts to condition pH electrodes in low ionic strength 'synthetic rain' produced relatively sluggish and unstable response. Discussions with Dr. William Koch of the National Bureau of Standards led to the currently implemented design feature of automatically storing the pH electrode in KCl solution during periods of inactivity. The KCl conditioning has greatly improved electrode stability and provided adequate response times for all but the most dilute rain samples.

Figure 4 presents results for pH and conductivity for a typical rain event. Figure 5 shows concentrations of some of the other important ions as a function of rainfall (vial number). From the measured concentrations, theoretical conductivities were calculated for each vial; a comparison between the measured and calculated values is shown in Figure 6.

Many rain events showed a washout phenomenon similar to that for the event above. Measurement of washout may be one of the most important applications of the present monitor, and changes in inlet size should be evaluated relative to loss of ability to resolve washout before changing the inlet.

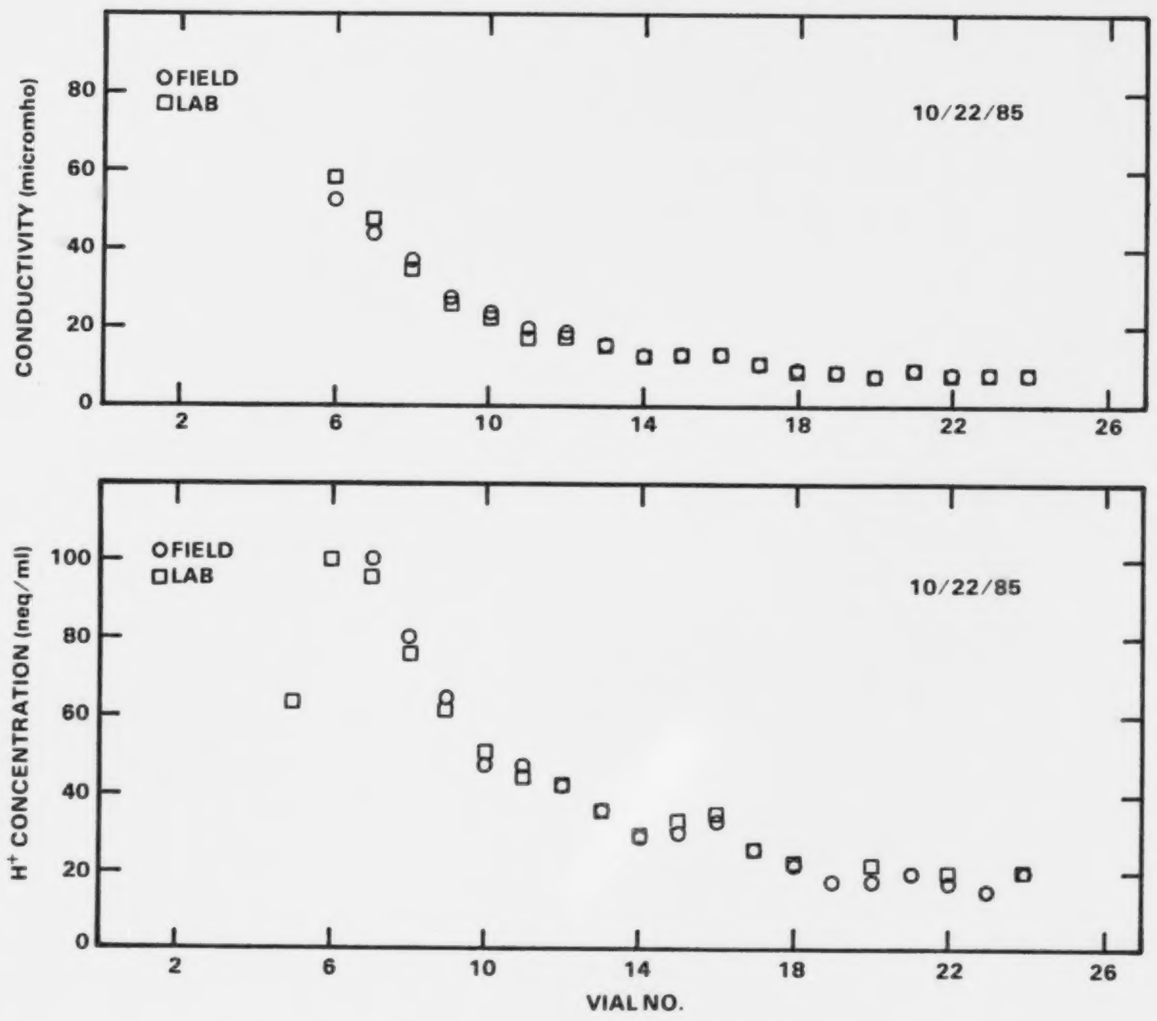


Figure 4. H^+ concentration and conductivity during typical rain event.

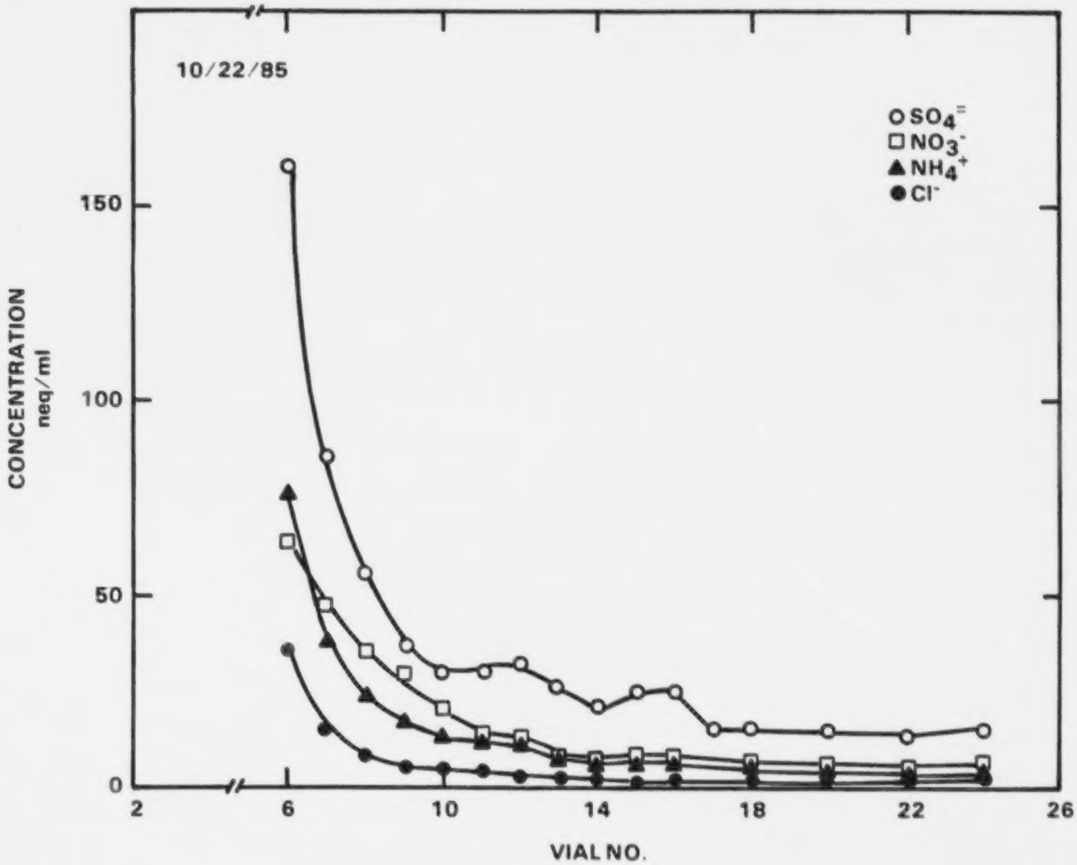


Figure 5. Chemical analysis of typical rain event.

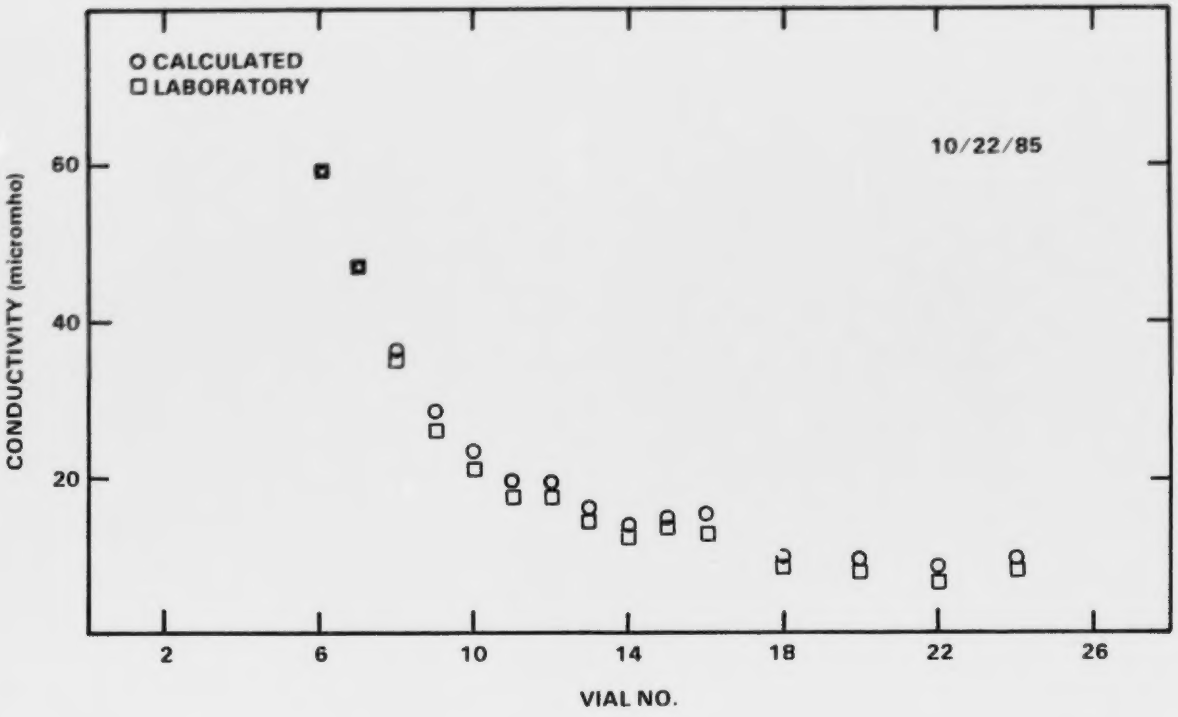


Figure 6. Conductivity calculated from measured concentrations of H^+, NH_4^+, Cl^-, NO_3^-, AND SO_4 .

Sample Stability Evaluation

A major concern throughout this project has been the extent to which rain samples change their chemistry under various storage conditions. This concern is particularly important in the standard rain collection methods, such as the Aerochem Metrics bucket method, where bulk rain is collected once weekly. Rain may sit as long as seven days at ambient temperatures. The rain monitor developed here has the advantage of storage of all samples at reduced temperatures (~5C).

Plots of sample stability for several different types of storage studies are presented in Figures 7-9. For the first study, 50 sample vials were prepared from a large quantity of artificial rain that consisted of an EMSL performance challenge quality control solution. All samples were stored at reduced temperatures in a refrigerator. At regular intervals, groups of five samples were taken out of storage, allowed to warm to ambient temperature, and analyzed in the laboratory. Results for the most important measurements are shown in Figure 7. The symbols represent the average value and the error bars indicate the calculated standard deviations for the results for the group of five vials. Some loss of ammonium was detected early in the study; this was accompanied by an apparent increase in hydrogen ion and concomitant increase of conductivity (hydrogen ion has the largest numerical specific ionic conductivity contribution). Unfortunately, these results were compromised to an unknown extent by the failure of the refrigerator for about one week near the 15 week point of the study.

To study the possible impact of biological activity on rain stability, a similar study to that above was conducted. In this case, a performance standard

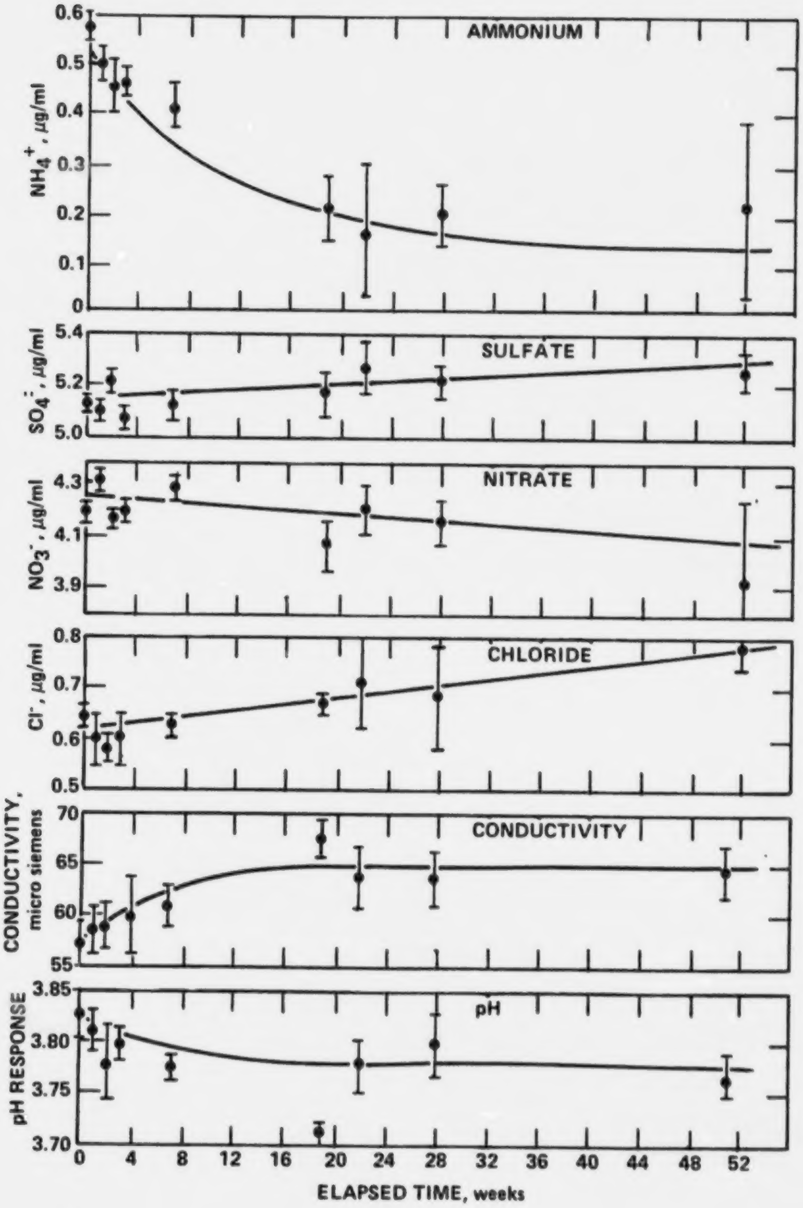


Figure 7. Plot of set No. 1 measurements vs. time.

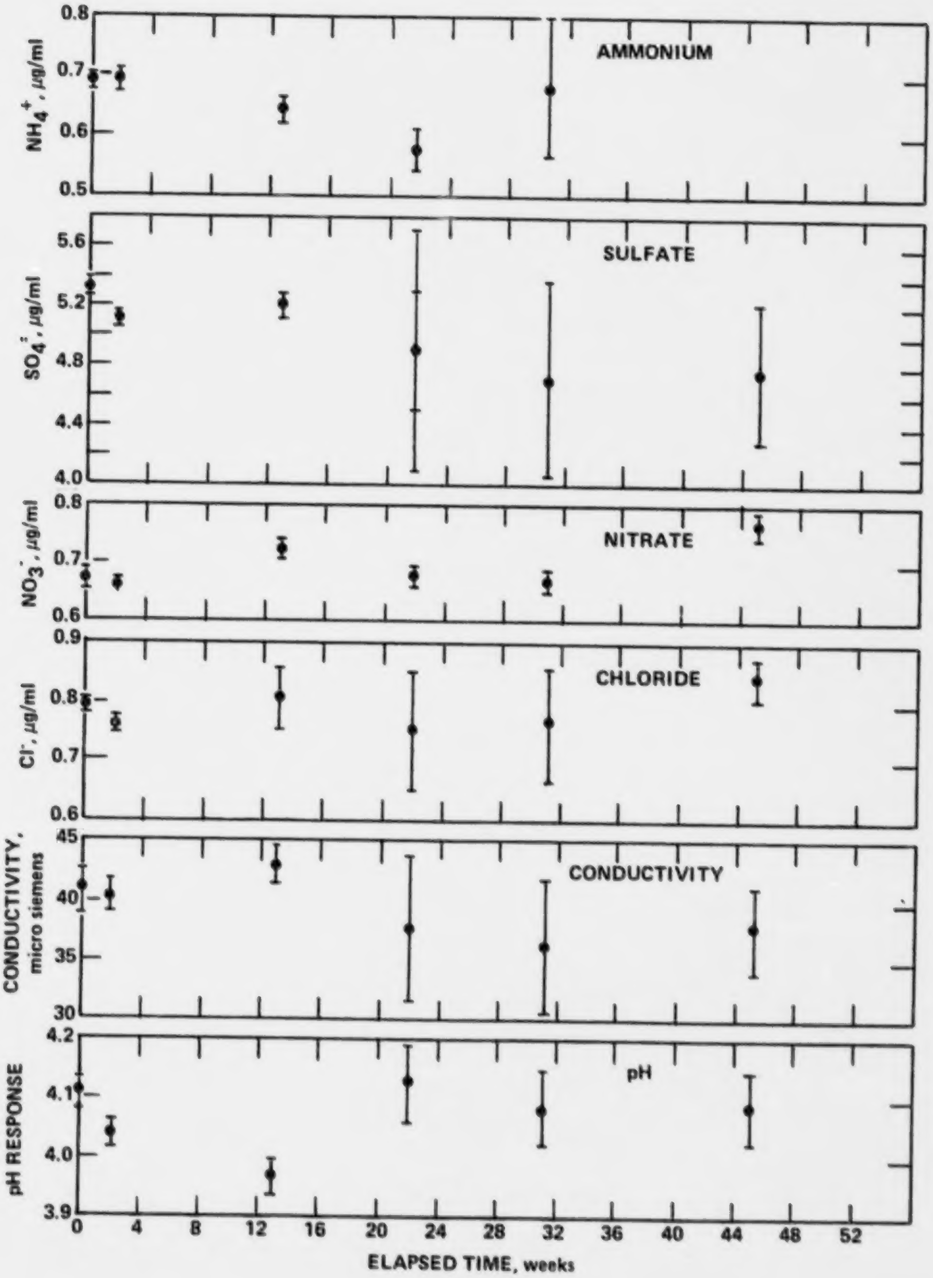


Figure 8. Plot of set No. 2 measurements vs. time.

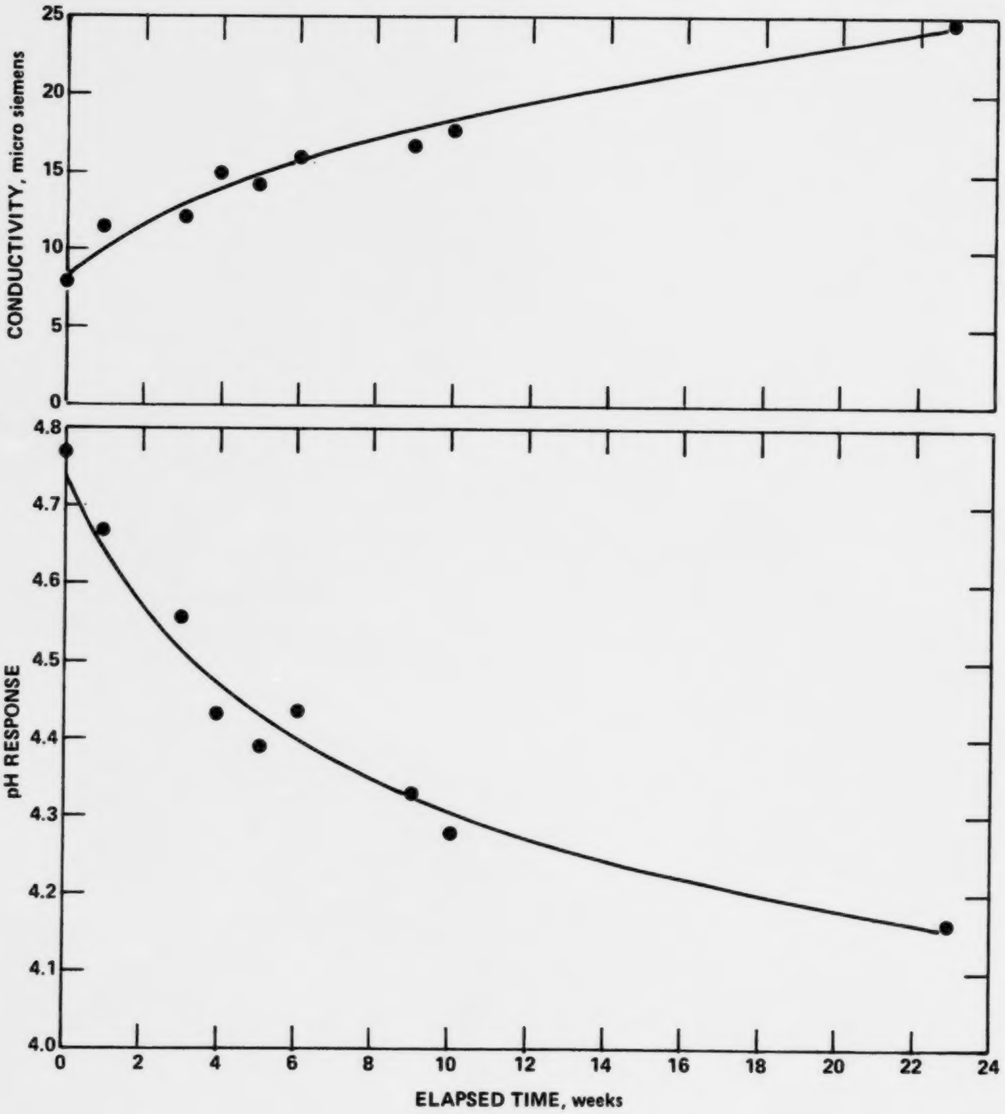


Figure 9. Plots of sample measurements vs. time for conductivity and pH. Samples stored in plastic containers at room temperature and exposed to light.

solution was mixed with an equal quantity of rain that had been obtained from an Aerochem Metrics bulk sample. The resulting solution was split into 50 vials which were stored under refrigerated conditions. Somewhat surprisingly, the observed changes of ionic concentration (Figure 8) were less for this set than for the set described earlier.

The effects of storage conditions on sample stability were studied in several additional ways. For each of several rain events, the bulk rain from the Aerochem Metrics sampler was taken and placed into groups of about twenty equivalent vials. These vials were then placed in differing storage environments such as room or refrigerated temperature, or under room light compared to storage in the dark. Not surprisingly, larger changes were found for samples stored under ambient conditions and exposed to the light. Figure 9 shows typical results for such samples: a decrease in pH (increase in acidity) is found together with a decrease in ammonium ion. These same trends were found for several of the studies.

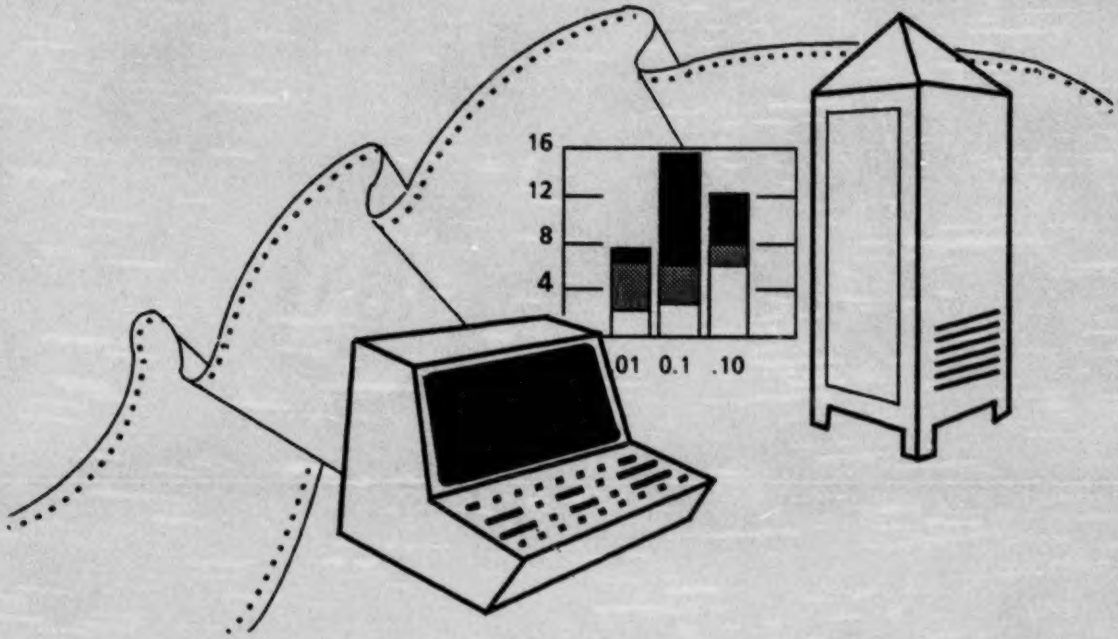
Overall, the magnitudes of changes over a seven day period were found to be significant but not dramatic. Thus, the present modes of network operation that use bulk collection and week-long storage may lead to a reasonable description of precipitation. However, conclusions drawn from the limited data provided here should certainly not be pushed too far. Storage of samples over several months may cause more significant problems.

The rain samples used in this study were not studied with respect to stability of organic acids, pesticides or other organic compounds, heavy metals such as lead, or possible tracer compounds, such as selenium. Such studies should be completed if monitors of the type described are to be used for measurement of those materials.

SP-4430-86-43

JULY 1986

ACID PRECIPITATION MONITOR MANUAL



Submitted to:

U.S. Environmental Protection Agency
Atmospheric Sciences Research Laboratory
Research Triangle Park, NC 27711

Under Contract No. 68-02-4033

NORTHROP
Environmental
Sciences

Special Publication

SP-4430-86-43

ACID PRECIPITATION MONITOR MANUAL

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SECTION 1

SYSTEM DESCRIPTION AND DEFINITIONS

1.1 INTRODUCTION

The acid precipitation monitor is designed to collect discrete rain samples, measure the pH and conductivity of each sample in real time, and store the samples for analysis later in a laboratory. All operations of the monitor are controlled by a Z-80 microprocessor that runs a program contained in a custom-designed electrically programmable read-only memory (EPROM) chip. The monitor is designed for stand-alone operation, but must be regularly serviced to remove any collected samples and to check the status of various solutions, calibrations, and supplies of compressed air and paper.

The purpose of this manual is threefold. First, this manual provides a description of the overall monitor and the manner in which it operates. Next, this manual contains all setup, calibration, and operating protocols so that the present prototype monitor can be operated in the field. Finally, schematics and drawings are presented of the present monitor so that additional monitors can be built by others. However, it is important to point out that detailed mechanical drawings and exact measurements are not presented for many of the components. These details have been intentionally left out to allow flexibility in monitor construction by other groups For example, the exact dimensions of the refrigerator compartment or the size of the housing are not important to the chemical or physical operation of the monitor and can be altered by the group building one of these monitors.

This manual describes the monitor in several levels of detail. To provide an overall view, brief descriptions are presented in this section for each of the major components. When appropriate, additional details concerning each of the components are referenced and presented in later sections of this manual.

1.2 OVERALL VIEW OF THE MONITOR

Figure 1-1 is a photograph of the acid precipitation monitor deployed at a field site. At the top are the rain sensor and the air-actuated cover mechanism. The body of the monitor is divided into two major sections, the upper compartment and the lower compartment. The photograph in Figure 1-2 shows the monitor with the door to the upper compartment open, and Figure 1-3 shows the details of the contents of this upper compartment. The major components housed here are the microprocessor electronics modules and power supplies, pH meter and conductivity meter, sample accumulation chambers, keypad and display, printer, rain cover mechanical components, and various solution containers. The upper compartment can be also accessed by a door in the back of the

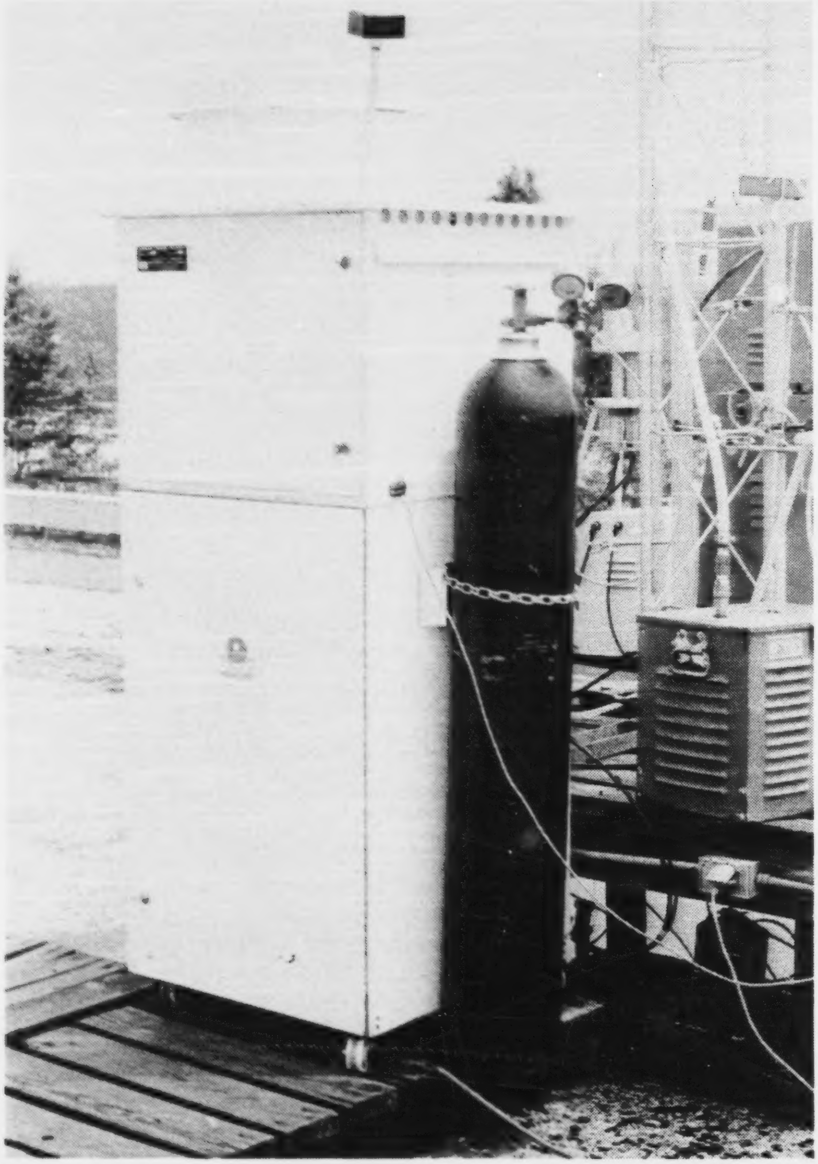

Figure 1-1. Overall View of Precipitation Monitor with the Rain Cover in the Closed Position. The compressed air cylinder is used to activate the cover mechanism.

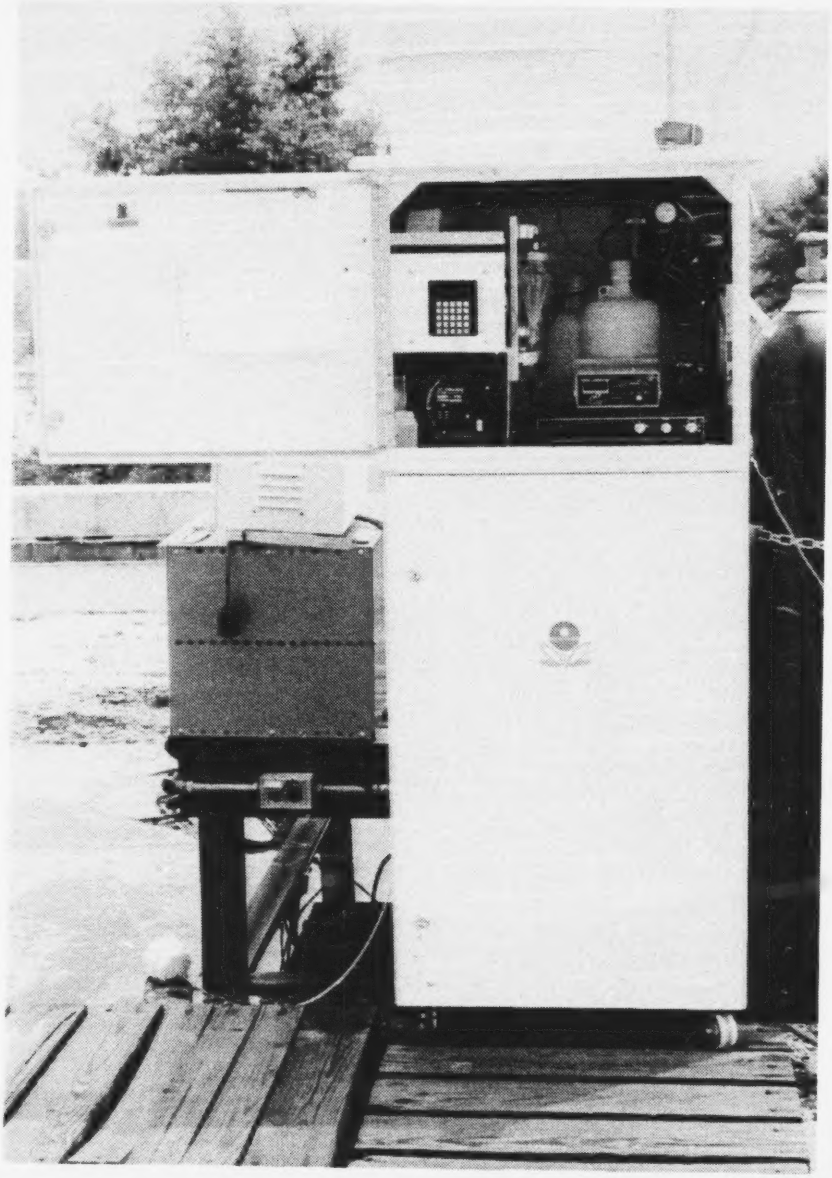

Figure 1-2. View of Rain Monitor with Upper Compartment Door Open.

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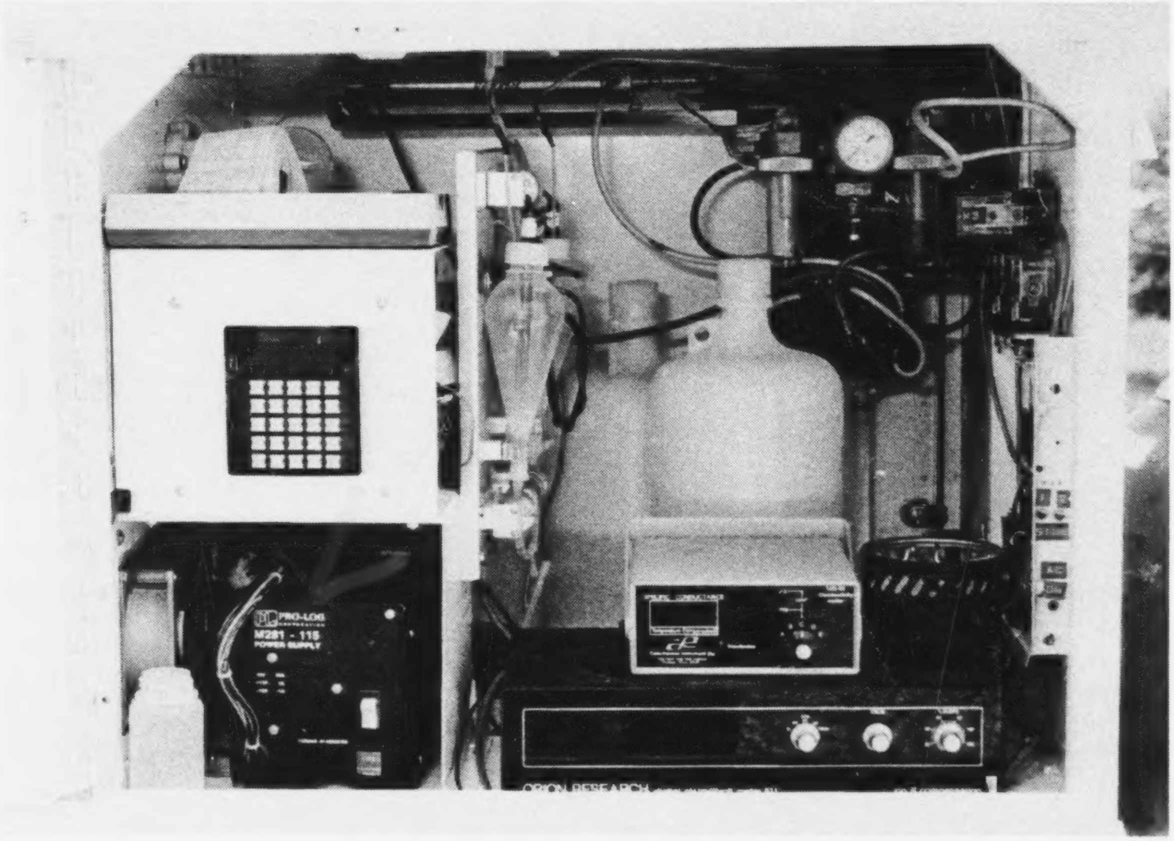

PRO-LOG
M281 - 115
POWER SUPPLY
ORION RESEARCH

Figure 1-3. View of the Upper Component. Rain cover hydraulic components: upper right; pH meter and conductivity meter: lower right; electronics power supply: lower left; keypad: upper left.

monitor. The Figure 1-4 photograph shows the monitor with the lower compartment door open. All components in the lower compartment are housed within a modified commercial refrigerator. Figure 1-5 shows the contents of the refrigerator including the sample carousel with sample vials, pH measurement chamber, and assorted liquid flow control tubing and valves.

1.3 MONITOR COMPONENTS

The major components are summarized below. The order of presentation generally reflects the sequence of events in processing a rain event. In a number of cases, reasons for selection of certain components are given. In other cases, advice is given or different approaches that might be used in the redesign or building of new monitors are discussed. These comments are intended to reinforce the third purpose of this manual as mentioned above: to allow other groups to build similar, but perhaps not identical, units.

1.3.1 Rain Sensor

The rain sensor is a modified Aerochem Metrics sensor, the sensor that is being used for the standard week-long bucket collectors in many present rain monitoring networks. This raised-grid-type detector senses the presence of rain by the ability of the ions in a water droplet to short out the path between a charged grid and electrical ground. Modifications to the commercially available sensor are required to ensure that spurious signals are not picked up by the microprocessor control unit. Details of these modifications can be found in Section 18 of this manual. (A drawing of this sensor can also be found in Section 18.)

1.3.2 Rain Cover Open/Close Mechanism

The present rain cover mechanism has been adapted from a system originally designed at the University of Minnesota by S. Krupa. Figure 1-6 is a photograph of the rain cover mechanism and Figure 1-7 is a schematic drawing of the action of the cover. In the closed position, an 18-in hemispherical Teflon-coated collection funnel is covered by a tight-fitting Teflon-coated aluminum lid with a gasket. When the rain sensor detects the presence of rain, the monitor microprocessor sends a signal to a series of air-pressure-actuated pneumatic cylinders that control the opening and closing of the rain cover. During opening of the rain cover, the aluminum lid rises, rotates away from the opening, and then drops out of the way to minimize the effects of possible splashing. The cover remains open until the rain event is over and the microprocessor directs the cover to close. To prevent excessive open/close cycles during mists or light rains, the present microprocessor system has been programmed to wait an arbitrary 1-h period after cessation of rain before sending a cover-close signal. To allow comparison to other rain monitors or to control additional equipment, extra terminal outputs have been made available on the side of the monitor.

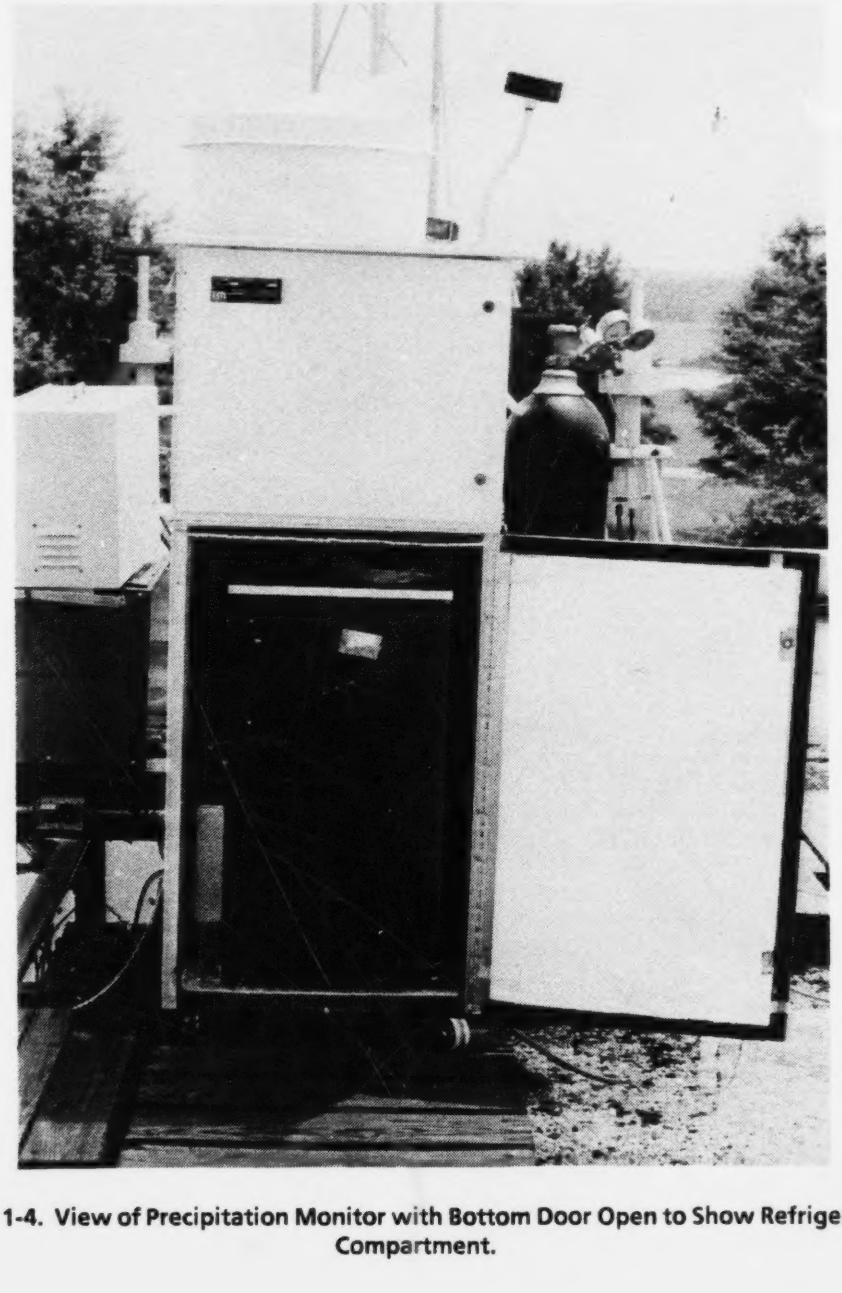


Figure 1-4. View of Precipitation Monitor with Bottom Door Open to Show Refrigerator Compartment.

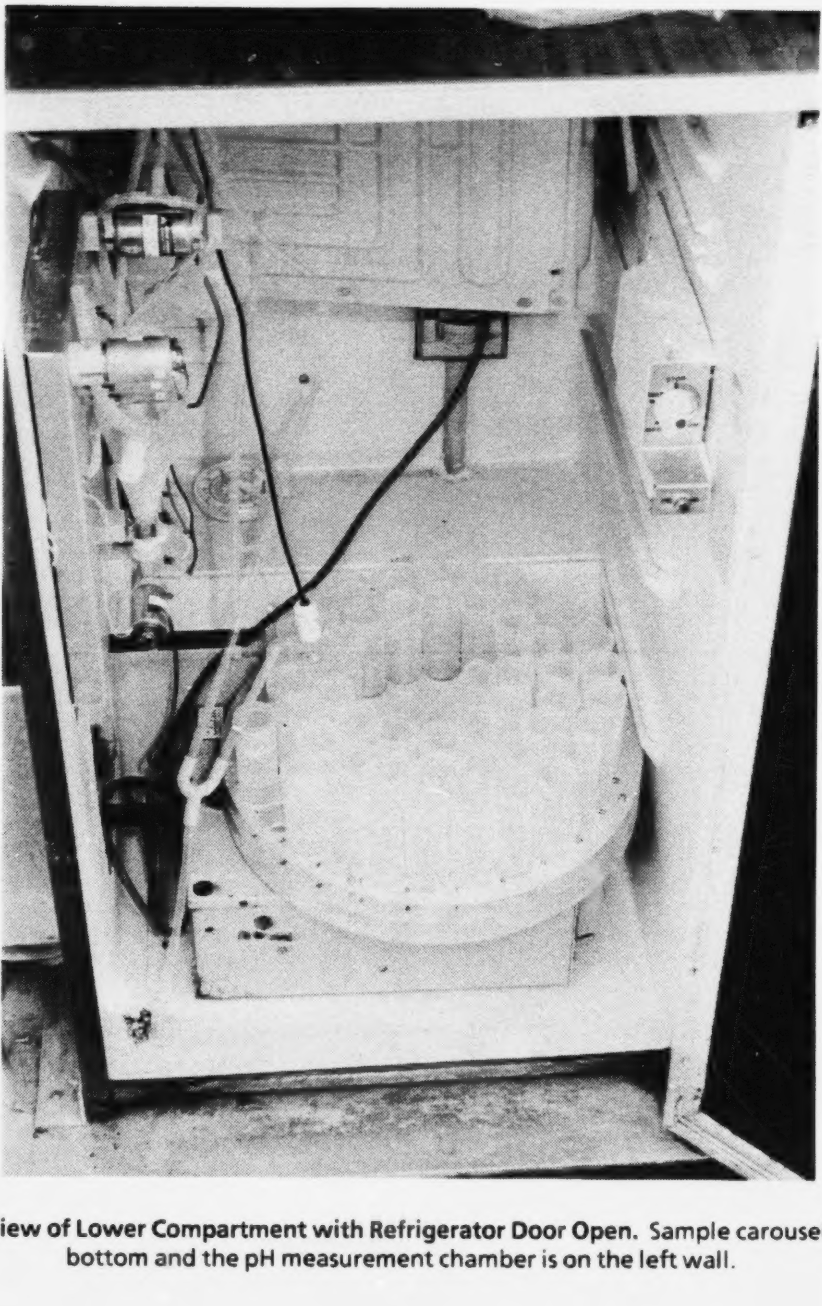


Figure 1-5. View of Lower Compartment with Refrigerator Door Open. Sample carousel sits on the bottom and the pH measurement chamber is on the left wall.

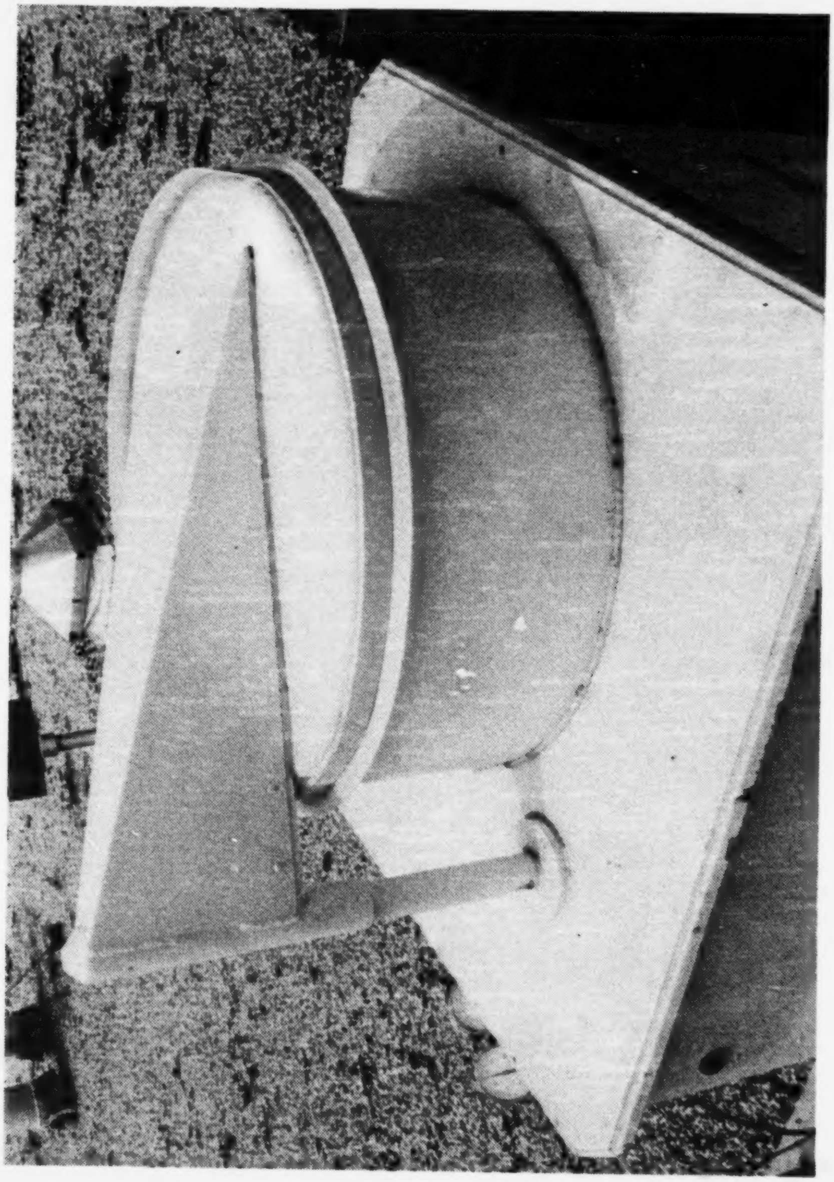


Figure 1-6. View of the Rain Cover Lid from Above the Monitor. In the presence of rain, the cover lid lifts, rotates, and drops away from the collection tunnel.

41

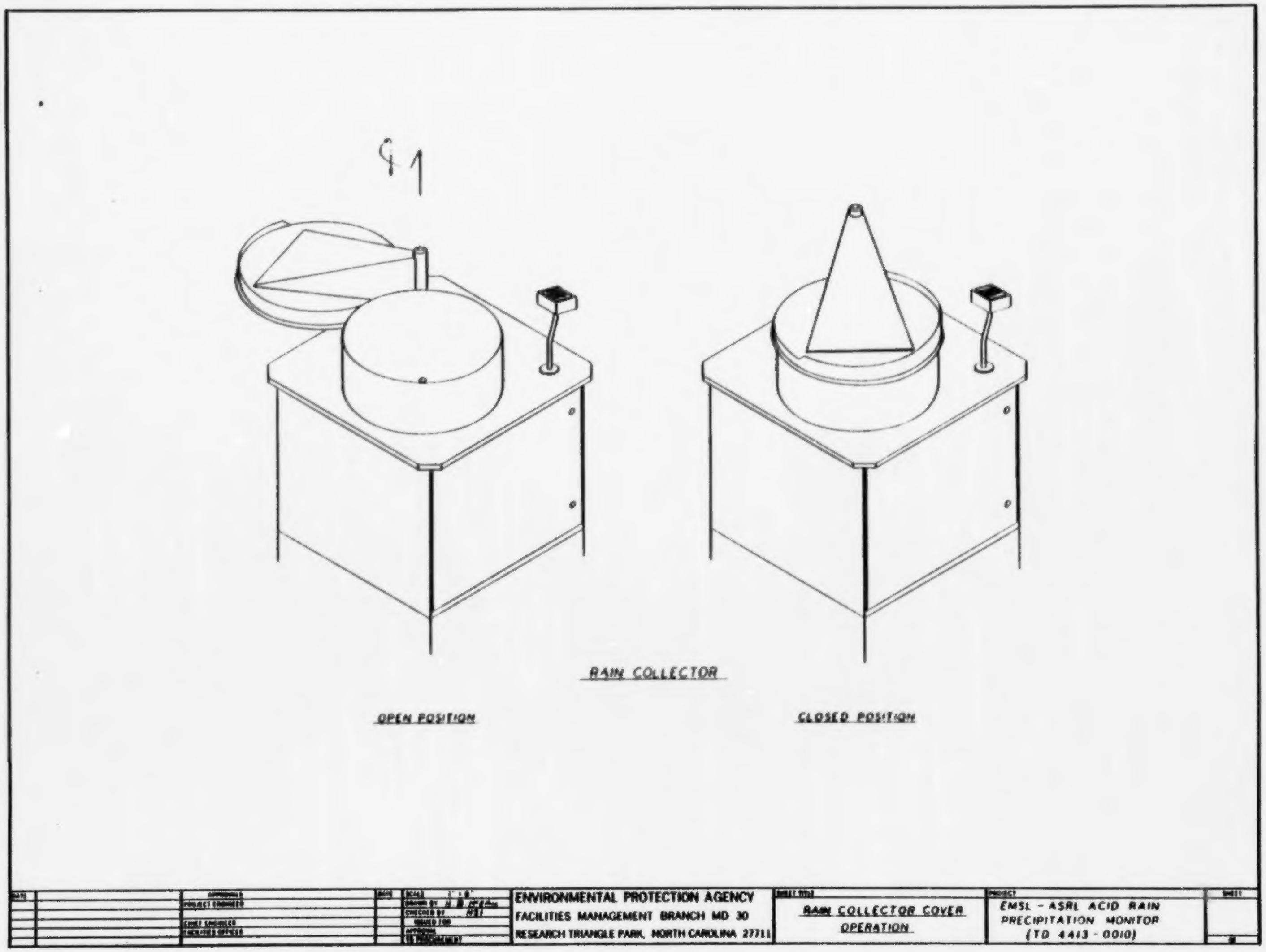

RAIN COLLECTOR
OPEN POSITION
CLOSED POSITION
APPROVALS
PROJECT ENGINEER
CHIEF ENGINEER
FACILITIES OFFICER
DATE
SCALE
DRAWN BY
CHECKED BY
ISSUED FOR
APPROVAL
ENVIRONMENTAL PROTECTION AGENCY
FACILITIES MANAGEMENT BRANCH MD 30
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711
SHEET TITLE
RAIN COLLECTOR COVER OPERATION
PROJECT
EMSL - ASRL ACID RAIN PRECIPITATION MONITOR (TD 4413 - 0010)
SHEET

Figure 1-7. Schematic Drawing of the Operation of the Rain Collection Cover.

The particular design of the rain cover mechanism is not critical to the operation of the present monitor. As noted above, the cover mechanism was adapted from a design from the University of Minnesota. The cover on the present prototype was obtained from them as one component of an entire rain monitor of a different design from the one here. All extraneous features were removed and the electronics were simplified. We do not present these details here because the construction of additional rain monitors will require construction of new rain covers and they will not necessarily resemble the one here. However, the size of opening is an extremely critical parameter. The present diameter size, 18 in., is too large for most applications. This size has the advantage of collecting a sample for every 0.01 in. of rain but has the disadvantage that only small rain events can be completely sampled. The present hemispherical cover has also been modified to include an overflow tube that provides an additional means of draining rain in case of excessive rain rates. This excess rain is collected in a separate container.

The operation of the monitor can be best understood by referring to Figure 1-8, which shows an overall schematic.

1.3.3 Rain Accumulators

Two separate, equivalent rain accumulation vessels are provided in the monitor. Figure 1-9 is a schematic of the accumulator section and Figure 1-10 is a photograph of the section. Each vessel is made of Teflon and contains an electrical level sensor and a conductivity probe. For the present monitor, the vessels were made by modifying separatory funnels that can be obtained easily from chemical supply houses. The thin, clear walls of these vessels provide a convenient means of observing the status of the rain collection activity. The electronic level sensors consist simply of two bare wire leads separated by a small air gap. Water rises in the accumulator until it covers this gap. Through the electrical conductivity of the rainwater, an electric circuit is completed that the microprocessor can sense. The amount of rain collected per sample can be varied by altering the height of the sensor in the vessel; the present sensors have been adjusted to trigger after 50 mL of collected rain. When sufficient sample has been collected, the microprocessor opens a solenoid valve (V2 or V3 in Figure 1-8) at the bottom of the accumulator that allows the water to drain to the pH chamber and to storage vials.

A conductivity sensor has been mounted in each accumulator. The signal from each sensor is fed to a conductivity meter with digital output (The microprocessor controls which probe is being examined by the meter.) The microprocessor queries the meter several times per second while the accumulator is filling, and accepts and stores the last value before the level sensor is triggered.

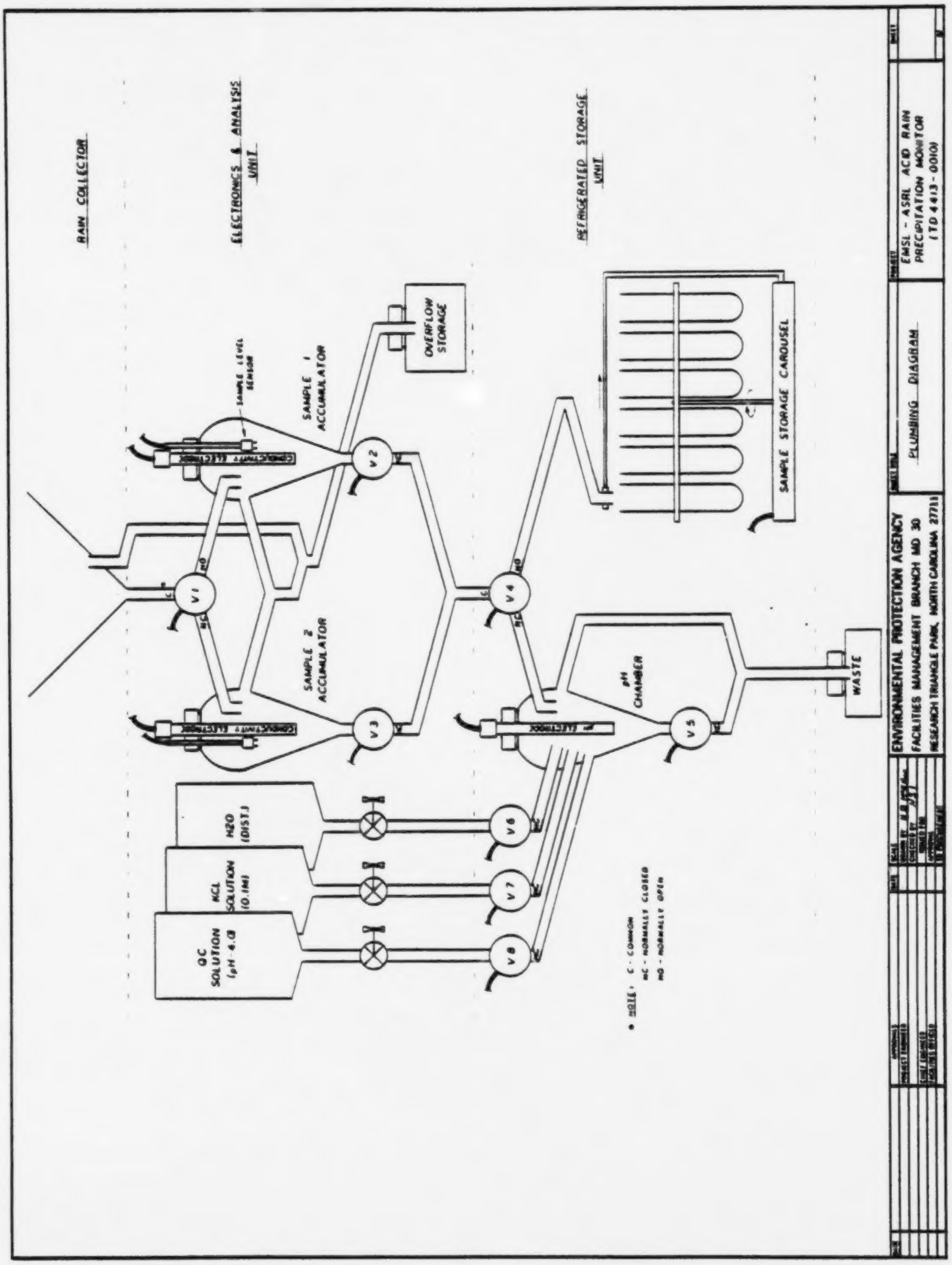

RAIN COLLECTOR
ELECTRONICS & ANALYSIS UNIT
REFRIGERATED STORAGE UNIT
SAMPLE 1 ACCUMULATOR
SAMPLE 2 ACCUMULATOR
SAMPLE LEVEL SENSOR
CONDUCTIVITY ELECTRODE
OVERFLOW STORAGE
SAMPLE STORAGE CAROUSEL
pH CHAMBER
pH ELECTRODE
WASTE
QC SOLUTION (pH 4.0)
KCL SOLUTION (0.1M)
H2O (DIST.)
V1
V2
V3
V4
V5
V6
V7
V8
C
NC
NO
NOTE: C - COMMON
NC - NORMALLY CLOSED
NO - NORMALLY OPEN
ENVIRONMENTAL PROTECTION AGENCY
FACILITIES MANAGEMENT BRANCH MD 30
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711
PLUMBING DIAGRAM
EMSL - ASRL ACID RAIN PRECIPITATION MONITOR
(TD 4413-0010)

Figure 1-8. Overall Schematic of Monitor.

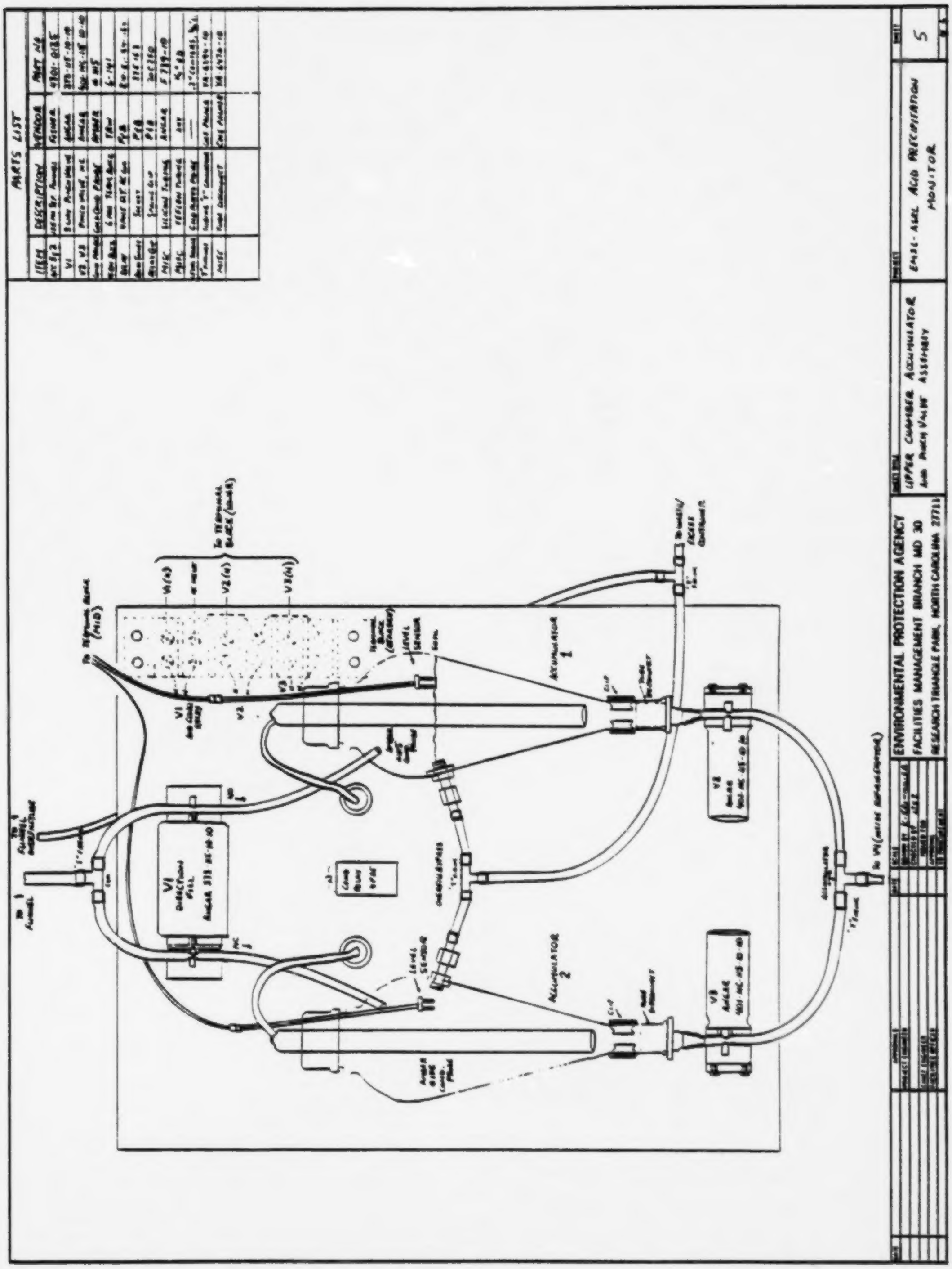

PARTS LIST
ITEM
DESCRIPTION
VENDOR
PART NO.
ACCUMULATOR 1
ACCUMULATOR 2
V1 DIRECTION FILL
LEVEL SENSOR
LEVEL SENSOR
V1(NC)
V2(NC)
V3(NC)
TO TERMINAL BLOCK
ENVIRONMENTAL PROTECTION AGENCY
FACILITIES MANAGEMENT BRANCH MD 30
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711
UPPER CHAMBER ACCUMULATOR AND PINCH VALVE ASSEMBLY
EM3E-ASEL ACID PRECIPITATION MONITOR
5

Figure 1-9. Schematic of Accumulator Section.

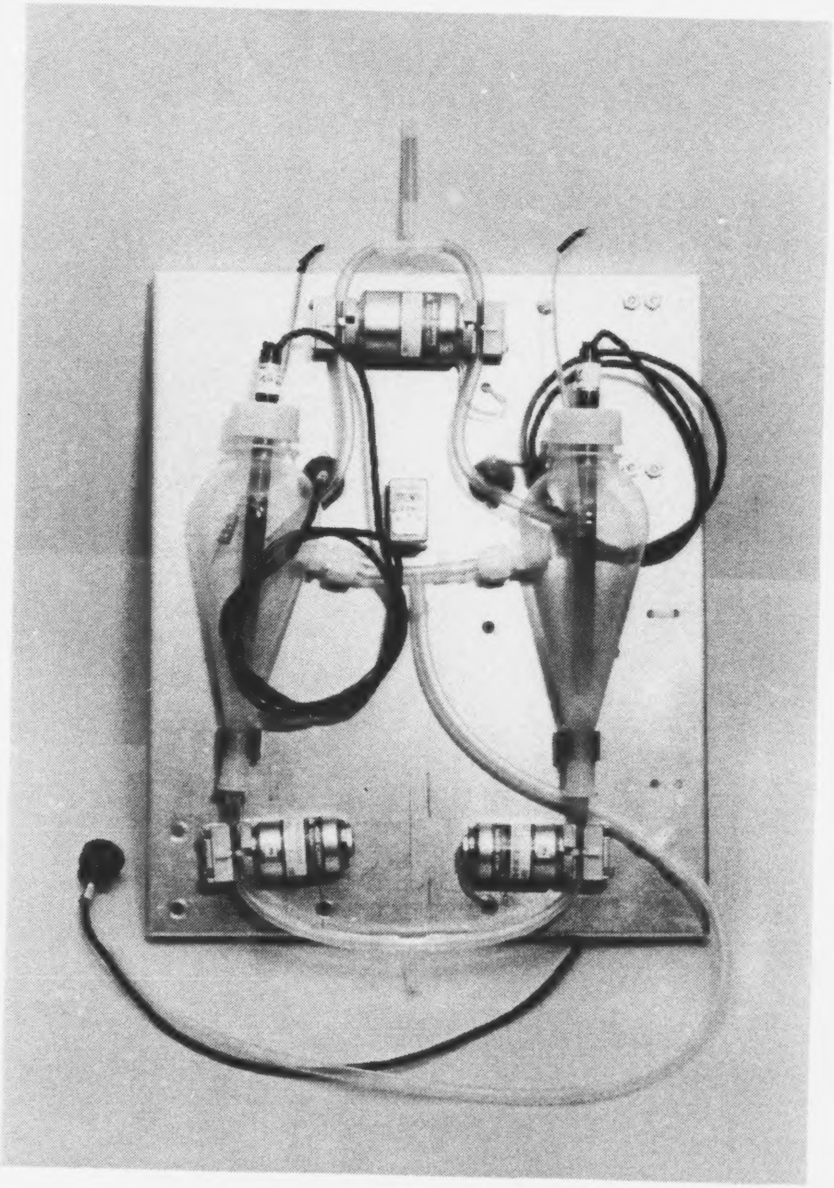


Figure 1-10. Photograph of Accumulator Section.

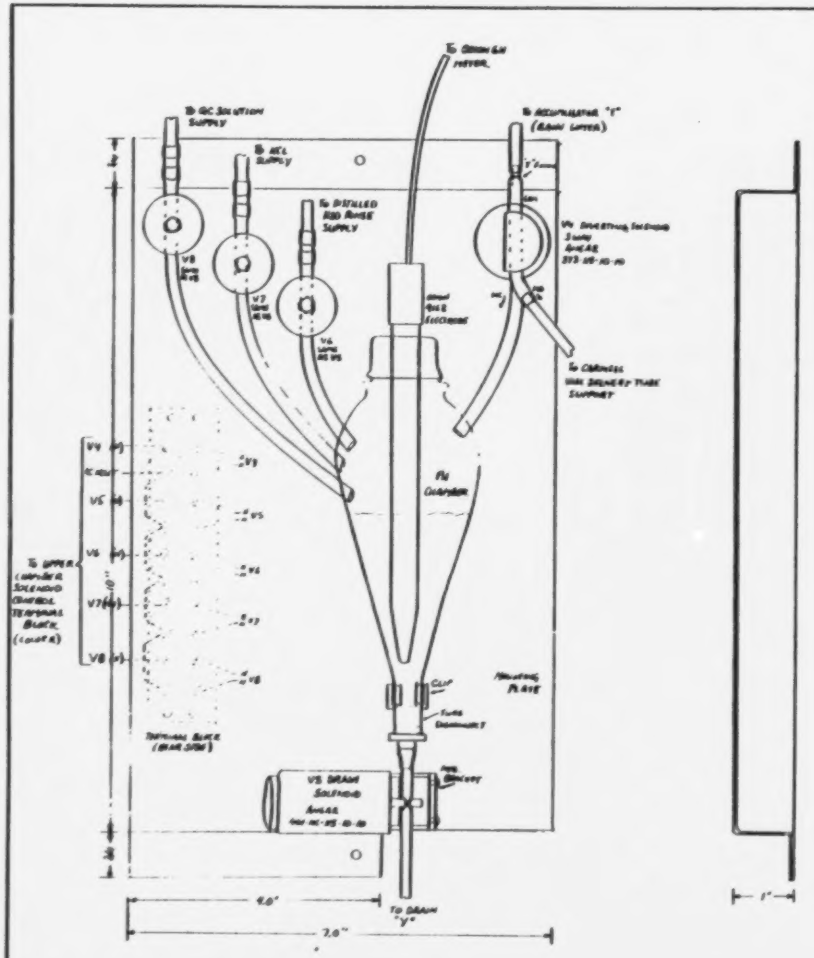
During operation of the monitor, a switching valve (V1 of Figure 1-8) under microprocessor control initially directs all rainfall toward the first of the accumulators (called Side 1 or Sample 1) until the level sensor is activated. The switching valve then directs subsequent rainfall toward the second accumulator; meanwhile, the collected rain in the first accumulator is routed toward first the pH measurement chamber and then toward the storage vials. Generally, the pH measurement process takes from 1 to 3 min to stabilize to a final value. If the second accumulator is filled before the pH measurement process is completed for the first sample, the collected rain is redirected toward the first accumulator (which has now been drained.) The entire contents of the second sample are sent to the sample vial carousel and are not processed for real-time pH. However, if the pH measurement process for the first sample has been completed by this time, the contents of the second accumulator will be processed for real-time pH. This process repeats itself until the entire rain event is over. *As an explanatory note, the major consideration that went into this particular choice for processing the rain was that it was judged important to make measurements of known accuracy for at least part, if not all, of the samples. If the rain rate were too rapid in a given event, the samples that did not have the pH determined in real time could still be measured later in the laboratory.

1.3.4 pH Cell

To measure the pH of a collected sample, approximately 15 mL of the rain collected in an accumulator is directed by Valve 4 (V4) toward a Teflon chamber. A detailed schematic of the cell is presented in Figure 1-11. A modified Teflon separatory funnel is used for the chamber. A photograph of the pH chamber and associated plumbing is shown in Figure 1-12. This chamber contains a research grade pH electrode and has 0.25-in. Teflon input lines for three separate solutions: distilled water, 0.1 M KCl, and a quality control solution. The distilled water is used to rinse the electrode between operations; the KCl is used as a high ionic strength storage solution for the electrode; and the quality control solution provides a check on the electrode response at specified programmable times. The pH measurement process is made under microprocessor control, during which the electrode response is constantly monitored. The microprocessor checks the pH reading until a long-term, stable response is observed. (As discussed later, the operator has some control over these measurement parameters.) Once the microprocessor determines that a stable reading has been obtained, Valve 5 (V5) is opened and the chamber is drained. The final pH reading is stored by the microprocessor, and the next measurement sequence is initiated.

1.3.5 Sample Storage Carousel

After part of a rain sample from an accumulator has been diverted to the pH chamber, the remaining solution is sent to a vial for storage. Vials are mounted in a 50-vial-capacity carousel that


To QC Solution Supply
To HCL Supply
To Distilled and Rinse Supply
To Orion pH Meter
To Accumulator "T" (Rain Water)
V4 Diverting Solenoid 3 Way Angar 373-15-10-10
To Carousel via Delivery Tube Support
Orion Ross Electrode
V8
V7
V6
pH Chamber
To Upper Chamber Solenoid Control Terminal Block
V4
V5
V6
V7
V8
Terminal Block (Rear Side)
Clip
Tube Grommet
Mounting Plate
Mtg. Bracket
V5 Drain Solenoid Angar 401-NC-15-10-10
4.0"
7.0"
To Drain "Y"
1"

PARTS LIST

ITEM	DESCRIPTION	VENDOR	PART NO
V4	3 Way Pinch Valve	Angar	373-15-10-10
V5,6,7,8	NC Pinch Valve	Angar	401-NC-15-10-10
pH Chamber	125 ml Separatory	Fisher	4301-0125
Te Block	10 Pos Term Block	TRW	10-141
pH Electrode	pH Electrode	Orion	91-62
Misc.	[illegible] Tubing	[illegible]	[illegible]
Misc	Silicon Tubing	Angar	F739-10
Fittings	"T" Connector	Cole Palmer	YA-6394-10
Misc	Tube Disconnect	Cole Palmer	YA-6376-10

ENVIRONMENTAL PROTECTION AGENCY FACILITIES MANAGEMENT BRANCH MD 30 RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711	SHEET TITLE Refrigerator pH Chamber And Pinch Valve Assembly	PROJECT EMSL-ASRL Acid Precipitation Monitor	SHEET 6

Figure 1-11. Schematic of pH Cell.

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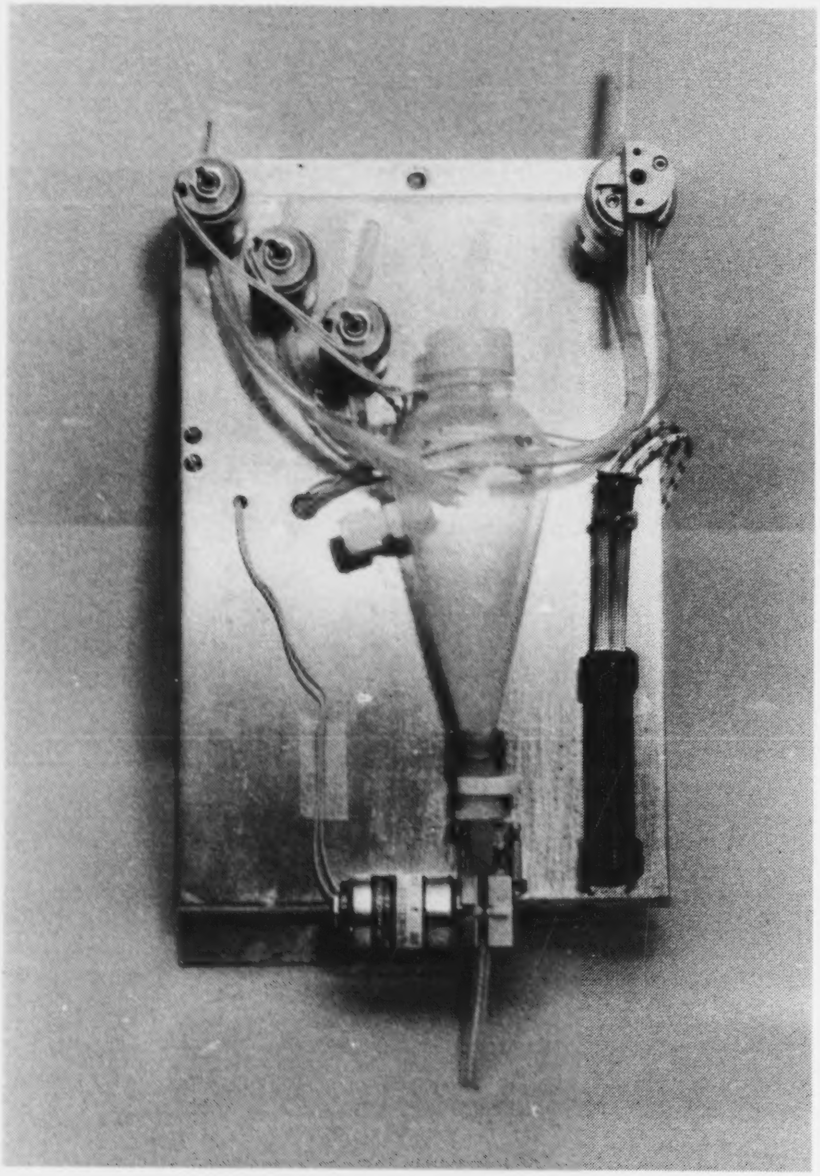


Figure 1-12. Close-up View Showing pH Measurement Chamber.

is located in a refrigerator. With the present system, an Eldex carousel is used that has the capacity for 50 vials, each of which can hold 50 mL of rain. This carousel does not provide a means for the microprocessor to determine the absolute vial position location. Therefore, an important part of the operating procedure for the station operator is to verify that the present carousel position is identified correctly by the microprocessor. (Note: For the construction of new rain monitors, a different carousel could well be considered.)

1.3.6 Refrigerator

To help prevent chemical change, the rain samples are stored slightly above freezing temperature in a refrigerator. Although the basic refrigerator is obtained commercially, it must be modified for inclusion in the rain monitor. To provide protection to the microprocessor electronics, special care must be taken to remove the possibility of electrical switching noise on the electric power caused by the refrigerator turning off and on. A zero-crossing mechanism is described later in this manual. To prevent freezing of the samples, a thermostat-controlled light bulb heat source has been placed in the refrigerator.

1.3.7 pH Meter

An Orion Model 611 research grade pH meter has been used in the present monitor. The meter is automatically temperature compensated. An Orion 91-62 electrode has been used because it responds quickly at the 5° Celsius temperature of the pH chamber. A special quality assurance procedure has been included in the microprocessor program so that the electrode response is automatically checked at programmed intervals.

1.3.8 Printer

An ALPS ASG 1100 printer is used to obtain a hard-copy output of all rain-related data generated by the microprocessor. The printed messages include data on rain cover open/closes, sample collection times, real-time conductivity and pH readings, sample vial position, and any power interruptions.

1.3.9 Conductivity Meter

A Cole-Parmer conductivity meter is used in conjunction with a pair of conductivity probes that have been manufacturer recommended for their low ionic strength sensitivity.

1.3.10 Sample Storage Containers

Polycarbonate containers that hold 50 mL are used. After sample collection each sample tube is capped and properly labeled according to its carousel position. To preserve the rain samples from chemical alteration, these vials should be stored under refrigerated conditions until laboratory analyses are completed.

1.3.11 Housing

The monitor housing has been constructed of sheet metal and placed on wheels for easier transportation. Provisions are made in the upper chamber area for cooling fans to help prevent buildup of heat around the electronics module during summer months sampling. A schematic of the overall housing is presented in Figure 1-13.

1.3.12 Solenoid Valves

Pinch-tubing valves produced by Angar are used for the control of liquid flow. Originally Mace Teflon solenoid valves were used, but these were found to be particularly susceptible to clogging by entrained particulate matter in the collected rain. The present valves operate by mechanically squeezing down on a pliable piece of silastic tubing. Excellent performance has been found, but care must be taken to replace tubing at approximately six-month intervals to counteract stiffening of the material.

1.3.13 Solution Containers

Four-liter polypropylene containers have been used in the present monitor for the storage of distilled KCl storage solution and 0.0001 N sulfuric acid quality control solution.

1.3.14 Keypad

The keypad and display unit have been shown as part of Figure 1-3. This component serves as the operator interface to the microprocessor that controls all monitor operations. Section 3 of this manual is devoted to a complete discussion of this unit.

1.3.15 Electronics Module

There are four electronic circuit cards enclosed in a card cage that interconnects their standard bus signals. A schematic of the card cage is shown in Figure 1-14. A power supply is located to the left of this card cage and supplies +5 V, +12 V, and -12 V to the system. Also, +12 V and -12 V ground are supplied to the relays and other circuits through a cable directly from the card cage. The four cards are: 1) the special purpose card, 2) the AC relay card, 3) the keyboard/display cards, and 4) the CPU (central processor) card. Each card performs a necessary function within the overall system and communicates with the others at either the card cage bus or through cables connected at or near the top edge of the cards. The main functions of the four cards are presented.

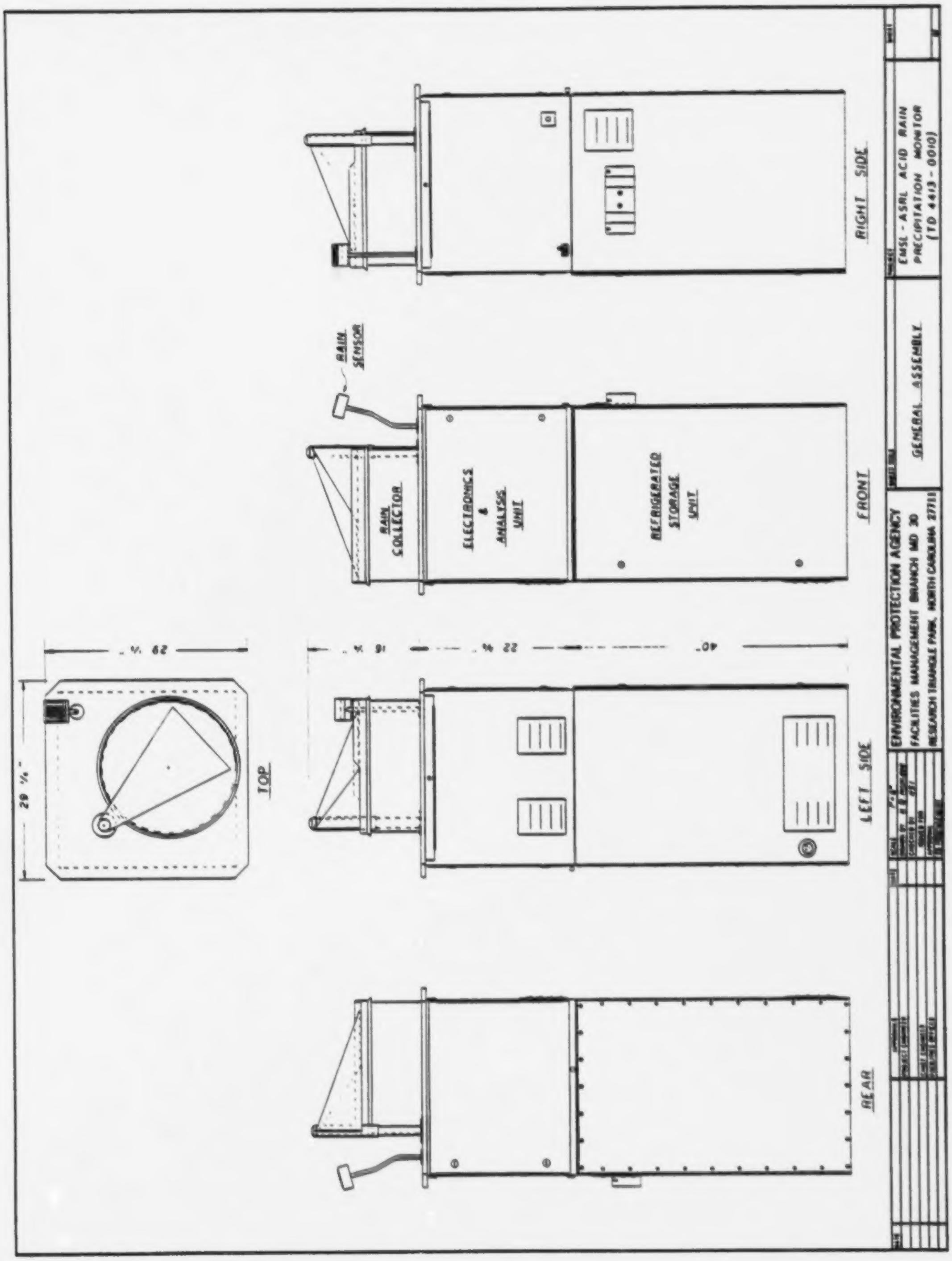

29 ¼"
29 ¼"
TOP
18 ¾"
22 ¾"
40"
RAIN SENSOR
RAIN COLLECTOR
ELECTRONICS & ANALYSIS UNIT
REFRIGERATED STORAGE UNIT
REAR
LEFT SIDE
FRONT
RIGHT SIDE
ENVIRONMENTAL PROTECTION AGENCY
FACILITIES MANAGEMENT BRANCH MD 30
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711
GENERAL ASSEMBLY
EMSL - ASRL ACID RAIN PRECIPITATION MONITOR
(TD 4413 - 0010)

Figure 1-13. Schematic of Overall Housing.

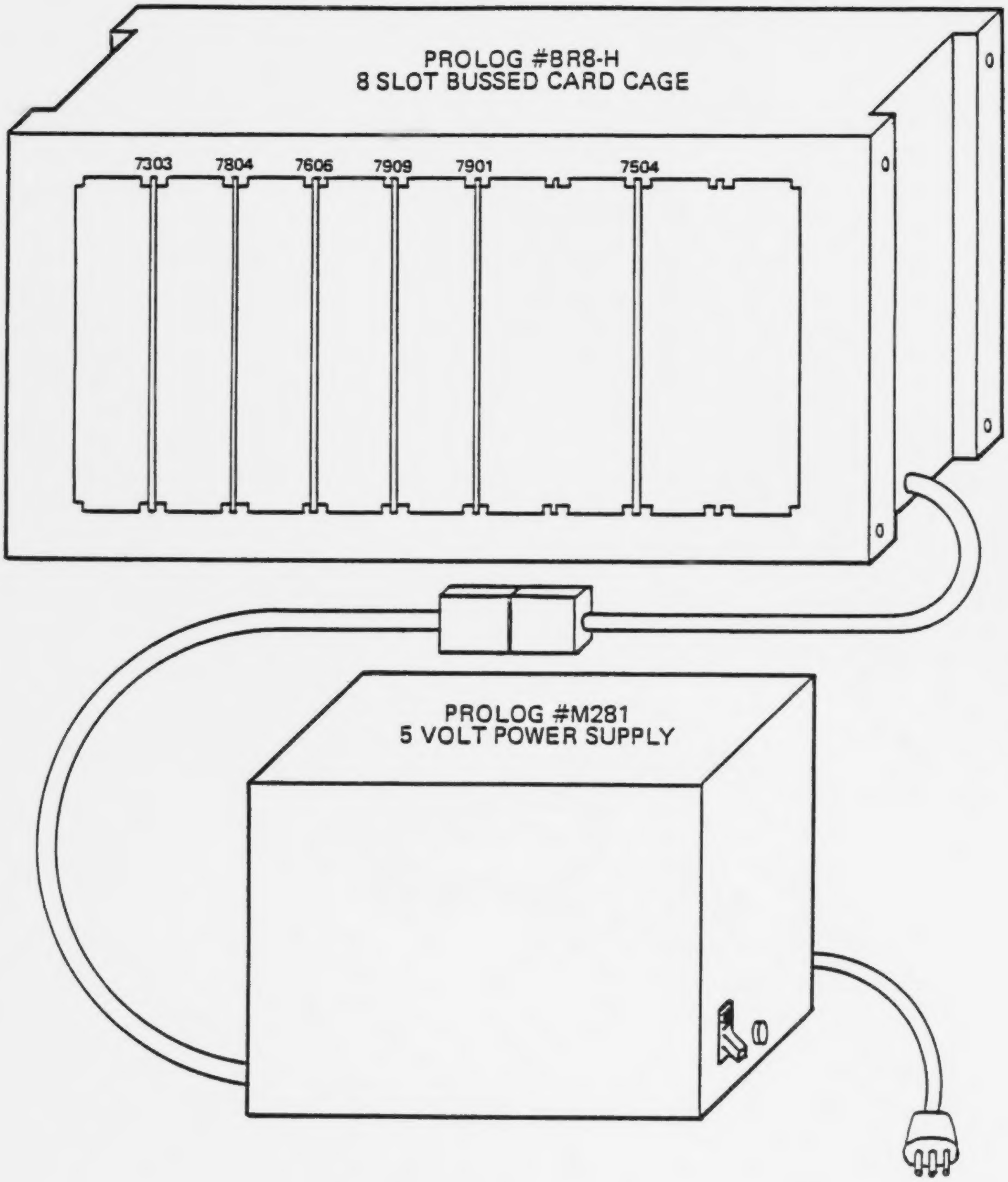

PROLOG #8R8-H
8 SLOT BUSSED CARD CAGE
7303
7804
7606
7909
7901
7504
PROLOG #M281
5 VOLT POWER SUPPLY

Figure 1-14. Card Cage and Power Supply.

Special Purpose Card

This card is the only noncommercial card in the system and contains integrated circuits interconnected by wire-wrapping their inputs, outputs, and supply voltages. One interconnect (IC) is the clock chip, which contains all the circuitry to keep time for the system. It has the capability of being set to a particular date and time and also generating a precise 500-ms (2 per second) signal. This signal is used for an input to a programmable down counter circuit located on the CPU card and results in the interrupt called TIMER that then reads the time contained in the chip (among other things). This card also provides the interface between the Orion 611 digital pH meter output and the microprocessor. This interface takes a request for one of the three digits of pH data and latches the data from the meter in preparation for the read operation that follows.

The interface between the ALPS printer and the microprocessor is also contained on this card. Digital ASCII characters are sent to this interface, which directs them to the printer and returns a signal called PRTACK (printer acknowledge) to the programmable down counter on the CPU card. The returned signal causes an interrupt named ACKPRT, which looks for another character to send, repeating the cycle if another character is available.

There are also three integrated circuits that can sense a wet/dry state across two electrodes. One of these, the cover circuit, is connected to the rain sensor grids for inputs and is followed by a delay chip that slows down the response to wet/dry states on the grids, thereby damping the cover opening/closing. The delay on open has been adjusted for about five seconds, while the delay on close has been set to a 1-h delay in the software. The other two wet/dry chips are connected to the probes located in the sample accumulators. The probes are adjusted so that the chips respond to a sample volume of 50 mL and create the signals that start the sequences for storing rain in the vials and determining the pH of the sample. Once the vial has filled, another circuit on this card is activated, closing contacts of a relay whose outputs are sent to the vial carousel. The carousel has been modified to include connectors for these signals and take them to the Manual Advance push switch. The carousel then advances to present the next empty vial to the delivery tube.

Conductivity measurements are also controlled by circuitry on the special purpose card. The 100-mV analog output from the conductivity meter is sent through a times 50 amplifier. The amplified signal is then read by an analog-to-digital converter.

A battery backup system is included on the card. This backup serves only to keep the clock running during power outages.

AC Relay Card

This card contains eight 115-V AC opto-isolated relays that control the eight Teflon solenoid valves.

Keyboard/Display Card

This card is the operator's interface to the system and contains a 24-key keyboard, an eight-character display, and two individual switches for enabling the keyboard and display. The keys have been dedicated to perform functions such as calling for the display of certain data, setting data into the system, and initiating functions of the system. These are fully described in Section 3 of this manual.

CPU Card

This card contains the Z80 microprocessor, 6K bytes of EPROM for program and constant storage, 2K bytes of RAM for read/write variables, and the counter/timer circuit for generating interrupts to the microprocessor. This card also contains a reset circuit that automatically starts operation of the stored program whenever power is applied (power-up).

1.4 SYSTEM DEFINITIONS

The use of certain names and acronyms in describing the system are explained for clarity.

POWER UP: The application of power to the system by means of the power switch on the DC power supply

DISPDATE: Display the date message

DISPTIME: Display the time message

DISP PH: Display the pH message

SET TIME: Set the time message as in 1405 (2:05 pm)

SET DATE: Set the date message as in 840626 (June 26, 1984)

SETSTAID: Set the station ID message as in 000000 thru 999999

SETDELPH: Set delta pH message as in 04 (program looks for pH readings that are 0.04 pH units apart to satisfy criteria)

SETQCDEL: Set QC delta time as in 12 (12 h between QC sequences)

SETVIAL#: Set the vial position number as in 01 (vial position is #1)

SETPHLIM: Set the pH reading time limit as in 05 (end pH reading after 5 min)

(variable): Parentheses around a name should be interpreted as "the contents of," as in (VALVES) = the contents of memory location VALVES

NAME: A label or name followed by a colon should be read as "the address of," as in TIMER: = the memory location whose address is TIMER:

SECTION 2

SYSTEM SPECIFICATIONS

Power requirements:	115 to 120 V AC, 60 Hz, approx, 230 W
Size:	approx. 80 × 80 × 190 cm
Weight:	approx. 125 kg
Temperature, operational:	approx. –5°C to + 45°C
Cover opening:	49-cm diameter, 1830-cm^2 area
Sample volume:	adjustable, preset to 50 mL
Rain equivalent per sample:	0.27 mm rain per sample
Total number of samples:	50 vial positions in carousel
Maximum rain capability:	13.5 mm rain

SECTION 3

KEYBOARD OPERATION AND USE

The keyboard/display card (nearest the operator) contains the interactive means to enter and read out data and variables within the operating system. A schematic of the keypad is shown in Figure 3-1. There are two switches located to the left and right of the eight-character light emitting diode (LED) display that are used to enable display and keyboard action. The switch to the left (SW1 in Figure 3-1) controls the display: selecting the UP position enables the display to show data and/or messages, and selecting the DOWN position results in the blanking of the display. The switch to the right (SW2 in Figure 3-1) of the display controls the enabling of the keyboard: selecting the UP position activates the keyboard, and selecting the DOWN position deactivates it. To view data or messages, the operator switches the left switch up. The right side switch should be switched up if it is necessary for the operator to make parameter changes, view a different type of data, start a printer function, or start the internal QC sequence.

3.1 DEFINITION OF KEYS

0-9: Number keys, used to enter required data
A: Display the DATE on the LED display
B: Display the TIME on the LED display
C: Display the pH on the LED display
D: Set the DATE
E: Set the TIME
F: Set the STATION ID
10: Set the DELTA pH value
11: Set the QC DELTA TIME value
12: Set the VIAL POSITION to a value
13: Set the MAX PH TIME LIMIT
14: Close the rain cover
15: Initiate the internal QC SEQUENCE
16: Print the current pH reading
17: Print the HEADER information block

PRO-LOG #7303
KEYBOARD/DISPLAY CARD

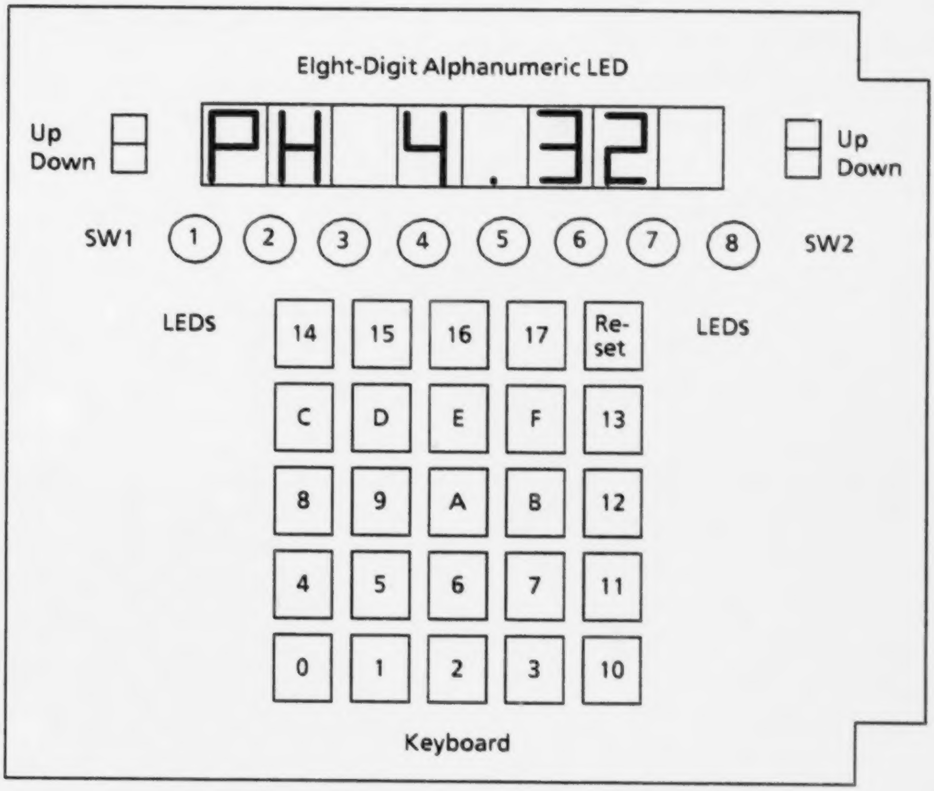

Eight-Digit Alphanumeric LED
Up
Down
PH 4.32
Up
Down
SW1
1
2
3
4
5
6
7
8
SW2
LEDS
LEDS
14
15
16
17
Re-set
C
D
E
F
13
8
9
A
B
12
4
5
6
7
11
0
1
2
3
10
Keyboard

Figure 3-1. Schematic of Keypad.

3.2 USE OF KEYS

Descriptions of the keys and their functions are provided below.

3.2.1 The DISPLAY Keys

Selecting Keys A, B, or C activates the display of either DATE, TIME, or pH DATA after the key-enable switch is returned to the DOWN position (deactivated), providing that the display enable switch is in the UP (enabled) position.

3.2.2 The SET Keys

Pressing Keys D, E, F, 10, 11, 12, and 13 (with both enable switches up) results in the display showing a message to the operator indicating the set function that is ready for data. The operator then uses the number keys to enter the prescribed data to satisfy the format requirements of the set function. Key D (SET DATE) requires the operator to key in six digits, for example, 840611 (June 11, 1984). Key E (SET TIME) requires the operator to key in four digits, such as 1425 (2:25 pm). Key F (SET STATION ID) requires the six-digit station ID number, formatted as 123456. Key 10 (SET DELTA PH) requires a two-digit value of the delta pH that will be used to determine when the pH reading has stabilized, for example, 04 (delta 0.04 pH units). Key 11 (SET QC DELTA TIME) requires a two-digit value (hours), during which the internal QC sequence will be continuously performed (the value determines the time between, not the start time). Key 12 (SET VIAL POSITION) requires the operator to key in the desired vial position, for example, 05 (indicating vial 5 is ready for sampling). Key 13 (SET MAX PH TIME) requires a two-digit value (minutes). This value represents the number of minutes that the microprocessor will spend waiting for a stable pH response. If this limit is exceeded, the sequence will abort.

3.2.3 The INITIATE Keys

Pressing Keys 14, 15, 16, and 17 starts or initiates an action of the sampler. Selecting Key 14 causes the raincover to close. Selecting Key 15 starts the internal QC sequence if no other sequence is occurring. Selecting Key 16 (print current pH) results in the printing of the current pH as read. Selecting Key 17 results in the printing of the HEADER information, which contains the system variables.

3.2.4 The NUMBER Keys

Keys 0 through 9 are used only to enter data as required for answering some other key request.

SECTION 4

OPERATION PROCEDURES

This section describes the detailed steps an operator takes to perform all aspects of (A) initial start-up operation, and (B) daily or weekly servicing. Interested parties should consult these procedures to answer a "how-to" question. The sampler has been carefully designed to give reliable operation under normal operating conditions. If the equipment malfunctions in some extraordinary circumstance, it will be necessary to follow one or more of the subsequent procedures.

****

WARNINGS TO OPERATORS

> Because of the high pressures inside compressed cylinders, follow all normal safety considerations.
>
> In event of expected severe storm activity, verify all equipment is securely fastened (immobilized).
>
> CAUTION - 115 V AC can be lethal. Use extreme caution when servicing during a rain event.

****

4.1 INITIAL START-UP

1. Open the upper chamber door and verify all subassemblies are arranged correctly, their connectors are secure, and all cables are arranged properly. If in doubt, consult the drawings.
2. Verify that the DC power supply is "OFF" before proceeding.
3. Connect a source of either air or nitrogen to the bulkhead fitting located at the right side of the sampler. Adjust the secondary side of the regulator to 45 psi.
4. Attach an extension cord to the AC bulkhead connector located on the left side, and connect to a power source of 115 V AC, 60-Hz cycle.

** CAUTION - AC now present **

The refrigerator, fans, and appliance outlet receptacle strip (and any equipment connected to it) should now be electrified.

Normal Characteristics	Abnormal Characteristics
Refrigerator cycles on (humming)	Circuit breaker interrupts
pH meter LED display light up	Noise from lower compartment
Printer executes a carriage return	Printer starts printing
Neon light is lit	No neon light (fuse blown)

5. On the DC power supply, switch the supply to the ON position. The ALPS printer should now begin to print the "POWER-UP" message and the state of the cover. If there is no print, turn the switch to OFF, wait a few seconds, and try again.
6. Using the keyboard, request the HEADER message to be printed (Key 17 when keyboard enable switch is in the UP position; see SW2 in Figure 3-1).
7. Ensure that the data are correct for STATION, DATE, and TIME, and are as desired for DELTA PH, PH EXIT TIME, QC DELTA TIME, and VIAL POSITION.
8. Use the keyboard to make any desired or necessary changes.
9. Inspect the refrigerator compartment and service as in Site Service Summary section (Section 5) of this manual.
10. The sampler should be operational, provided the operator has serviced the needs of the carousel, verified that all solutions are available for use, and verified that the DATE/TIME is correct.

4.2 DAILY OR WEEKLY SERVICING

During a period of operation without any rain, the operator should visit the sampler to verify the ready status as often as practical. At these visits, the operator should check the following.

1. Verify the consumables are adequate to last until the next visit.

   Paper supply - is there enough printer paper? Replace if necessary.

Distilled water - is there enough for operation? Refill as required.

KCl solution - is there enough for operation? Refill as required.

QC solution - is there enough for operation? Refill as required.

Air supply - is there enough? Replace air cylinder if necessary.

2. Check the printer tape for signs of ink failure. Replace if needed.

3. Check the printed data since the last visit. Look for any problems in the DATE/TIMEs, HEADER information, or frequency or results of the internal QC solution calibration. If the power has failed between visits (as seen by the POWER-UP message on the printout), verify that the DATE and TIME are correct. If not, use the keyboard to enter the correct data. Also, the results of the QC sequence should all be written 0.04 pH units of the solution's expected value. If any are outside this range, the operator should either replace the solution or perform the Buffer 3.00/7.00 calibration to identify any problems.

4. Look inside the refrigerator to check that the VIAL POSITION agrees with the printer's value. (Look on the printer tape for the last VIAL POSITION message and compare to the physical position.) If the two do not agree, use the keyboard to set the VIAL POSITION.

5. Verify the rain detector is operational by wetting the grids with a few drops of distilled water. The cover should sequence to the fully open position. If the cover fails to open, verify the air cylinder has pressure more than 45 psi. Use a clean KAYDRY towel moistened with distilled water to clean the inside of the collection funnel.

6. Take approximately 50 mL distilled water and deliver to the funnel. After all water has had a chance to accumulate in a chamber, toggle the correct MANUAL SEQUENCE SWITCH to initiate a sample sequence. This will rinse the plumbing associated with this sample side (note that this water will be delivered to a vial and can be used after collection as a blank for the system in analysis of data). Take another 50 mL distilled water and deliver it into the funnel. Repeat the previous procedure for the alternate sample side.

7. After the rinse procedure has been performed, again take a KAYDRY towel and dry the funnel collector. Now verify that the COVER CONTROL switch is in the NORMAL position and press Key 14 of the keypad to close the cover.

8. The sampler is now ready to operate until the next visit; however, the operator can remove any vials that have been acquired as a result of his visit to maximize the number available in case of rain. The operator must then use the keyboard to enter the VIAL POSITION that agrees with the physical position of the carousel.

9. At this time the operator should tear off the printer tape for logging into the sampler notebook. For clarity, the operator should request the HEADER print message to start the next tape strip. (Use Key 17 on the keyboard with keyboard enable switch up.)

If there was a rain event during the previous sampling period, the above procedures should also be followed. In addition, the operator should cap the rain sample vials, prepare labels for them, remove them from the carousel, and replace with empty ones. The data contained in the printer tape should be noted, and the sampler logbook updated to record these data concerning the event.

SECTION 5

SITE SERVICE SUMMARY

Each time the sampler is visited by the operator, the following steps should be performed to verify the operational status of the monitor. It is not necessary to follow them in order; however, if all steps are done, the sampler should be ready to sample subsequent rain events.

1. Open the top compartment and look at the printer listing. If the messages are legible, continue; if not, replace the pen.
2. Switch the Display Enable switch (SW1 in Figure 3-1) to the UP (enabled position) and check the time in the display. If it is not correct, use the keyboard to set TIME.
3. Look on printer listing for any cover openings/closing messages and any sample messages (e.g., did it rain?). If there are none, continue. If there was rain, open the refrigerator compartment and carefully remove the acquired samples, cap them, and label them. The vials should be removed as quickly as possible to either a cold shipping box or the laboratory cold storage location. The sampler logbook should be annotated to record the data from the printer corresponding to each sample. NOW IS THE TIME FOR GOOD RECORD KEEPING.
4. Examine the carousel and vials in the refrigerator. Replace empty vials for any removed as in Step 3. Realign the carousel, and use the keyboard to set the VIAL POSITION to reflect the ready position.
5. Open the top rear door and verify the solutions are adequate. Refill any as required.
6. Check the air/nitrogen gas supply tank pressure. Replace if required.
7. Check the rain detector/cover mechanism by wetting the sensor. The cover should sequence open. Then, using Key 14, close the cover. During the open time, wipe the funnel of any condensation or residual rain.
8. Check the latest HEADER message on the printer tape. Verify all data and defaults as required. Make corrections as required.
9. Perform a primary calibration of the pH meter if more than one week has elapsed since the last one.
10. Configure the fans, air openings, and/or heaters as required for the expected weather conditions to come.

SECTION 6

HINTS FOR RECORD KEEPING

At the very minimum, a logbook should be kept to physically store the printer tape. The operator would be well advised to also note any periods of rain and any other observations he can make to interpret the data acquired with the sampler. After a rain day, it is very important to collect any acquired vials, cap them to prevent evaporation, and label them with a number system that can be associated with the printed tape.

Because the sampler starts numbering vials with #1 every time the power is reapplied, there can be several number 01 vials if power outages occurred at the site. Also note that when power is applied to the sampler after a power outage, the vial carousel will rotate, thus resulting in empty vials within a sequence of filled vials. One other feature should be noted: when the cover closes after a rain event, the time is noted; and after one hour, the sample accumulators are emptied into the next available vial. This rain is the "leftover" rain that did not make a complete 50-mL sample. Its volume can range from 0 to more than 50 mL if both accumulators contained samples but were not processed.

SECTION 7

DAILY/WEEKLY MAINTENANCE

The only maintenance required for the sampler is to verify that the valves that control the routing of rain and solutions are operating correctly. If not, they must be replaced. The operator can detect problems by observing the fluid flows and noting any that appear sluggish compared to the others.

The suggested procedure for valve replacement is to power down the sampler at the main breaker box associated with the sampler AC, cut the two wires to the valve, disconnect the plumbing connection, and unscrew the support bracket. Using the same bracket with a replacement valve attached, reattach it. Next, resolder the two wires of the new valve to the cut wires that led to the problem valve. After the plumbing fittings have been reconnected, the sampler AC can be reapplied. Check the neon light for the "ON" status. If it is out, replace the fuse. Operate a sequence that will test this new valve to verify that the problem has been remedied.

SECTION 8

SOLUTION PREPARATION

8.1 QC SOLUTION

The prepartion of this solution requires use of precise and volumetric glassware. The final pH of the solution should be 4.00.

1. Using a volumetric pipet, dilute 4.000 mL of 0.1000 N sulfuric acid solution to 4.000 L with deionized (DI) water, **OR**
2. Using a volumetric pipet, dilute 20.00 mL of 0.1000 N sulfuric acid solution to 20.00 L with DI water.

8.2 KCl SOLUTION

The preparation of this solution does not need to be exact because it is used simply as a storage solution for pH electrodes.

1. Dissolve 29.8 g of dried KCl in 4.0 L of DI water, **OR**
2. Dissolve 149 g of dried KCl in 20 L of DI water.

8.3 CONDUCTIVITY STANDARDS

These standards are prepared from a purchased 0.005 M KCl solution.

72 µmho standard (0.0005 M). With a volumetric pipet, dilute 50.0 mL stock solution to 500 mL with DI water.

36 µmho standard (0.00025 M). With a volumetric pipet, dilute 25.0 mL stock solution to 500 mL with DI water.

7.2 µmho standard (0.00005 M). With a volumetric pipet, dilute 5.00 mL stock solution to 500 mL with DI water.

8.4 DEIONIZED WATER

Deionized water should be obtained from a laboratory supply where the conductivity of the water is monitored. If the monitor light is out on the filtration system, do not use the water.

8.5 CALIBRATION BUFFERS

Calibration buffers are used as supplied by the distributors.

SECTION 9

CALIBRATION PROCEDURES

The accuracy of real-time pH measurements depends on the care taken in maintaining the Orion 611 meter's electrode. Primary calibration of the meter consists of introducing the electrode to certified buffer solutions in vials external to the pH chamber, consistent with normal laboratory practice. An internal QC solution provides an indication of electrode/meter stability during normal operation of the monitor. Frequency of primary calibration should be either weekly or whenever the quality control response degrades, as indicated by the results listed on the printed tape.

9.1 PRIMARY CALIBRATION

1. Prepare two vials with certified buffer solutions of 3.00 and 7.00 (nominal) .
2. Remove the pH electrode from the pH chamber by pulling up on it, being careful not to strike any obstacles when lifting it out.
3. Using distilled water, rinse the electrode thoroughly, capturing the excess water in a waste beaker.
4. Place the electrode into the buffer 7.00 solution vial. Using the keyboard, request "print pH" to record the initial response.
5. After the meter attains a final reading, again request "print pH." If the response is more than 0.02 pH units off from expected, use the meter's calibrate control to adjust to the desired value. Again, after a minute wait for stability, and print the pH.
6. Remove the electrode from the buffer, and rinse thoroughly.
7. Place the electrode into the buffer 3.00 solution vial. Using the keyboard (key enable switch up) request "print pH' (Key 16) to print the time and initial pH response on the printer tape.
8. After the meter attains the final reading, (approximately three minutes), again request the "print pH" to record the final value. If, at this time, the response is more than 0.02 pH units off from expected, use the meter's slope control to force the correct value. Wait about a minute to verify stability; then request "print pH" to record the adjusted value on printer tape.
9. Iterate steps 3 to 8 until no adjustments are necessary.

10. Rinse the electrode with distilled water and replace into the pH chamber, making sure the tip of the electrode is near the bottom of the separatory funnel but not touching the side walls.

9.2 QUALITY CONTROL SOLUTION CHECK

1. Using the keyboard (key enable switch up), request a QC Sequence (Key 15).
2. Verify that all steps in the sequence are completed as desired: pH chamber empties, rinse water is introduced into the chamber, chamber drains, and QC solution is introduced; after the reading is acquired, the message is printed, the QC solution drains, and the KCl is introduced.
3. Note the printed message as to the accuracy of the response. If the response is more than 0.04 pH units off from that expected, it will be necessary to change the solution and/or perform the primary calibration.

9.3 CONDUCTIVITY CALIBRATION

The calibration of the conductivity probes in the two accumulators normally takes place *in situ*. Preparation of calibration solutions is described in Section 8 of this manual.

1. The rain cover may be opened either through artificially wetting the rain sensor or by switching the cover control toggle.
2. Using the keypad, the default time-out for a pH measurement should be changed to one (1) minute. (Use Key 13 to set pH time-out). Reduction of this parameter allows the conductivity calibration to proceed more rapidly.
3. The three conductivity solutions may be poured through in any order, but the usual sequence is 72, 36, and 7.2 µS. Pour enough of the first calibration solution through the rain cover to cause each of the accumulators to be filled (approximately 100 mL). This step serves to rinse out the accumulator and ensure an accurate calibration.
4. Now, pour in additional calibration solution to again nearly fill the first accumulator. Watch the digital readout of the conductivity meter. When it has stabilized, push the key on the right inside edge of the upper housing labeled "Side 1." This triggers the emptying of the first accumulator and switches the directional valve to Side 2. The conductivity for the first accumulator will be printed out at the end of one minute.
5. Repeat step 4 for the second accumulator with the exception that the switch "Side 2" should be pushed after the conductivity reading stabilizes.

6. Steps 4 and 5 are then repeated for each of the other two calibration solutions.
7. Generally, the span never needs to be adjusted on the conductivity meter, but when it does, the meter manual should be consulted. Span adjustments are made with a screwdriver adjustment to a potentiometer housed inside the front cover of the meter.
8. At the end of calibration, the default pH exit-time should be reset to the original value (using Key 13).
9. Close the cover using Key 14 on the keypad.
10. A number of vials will have been filled during this process. Usually, the used vials should be replaced and the carousel turned back to the starting position. If so, make sure that the microprocessor has the correct vial position stored in memory.

SECTION 10

QUALITY ASSURANCE

The monitor has been designed to have an automatic quality control solution processed at programmable intervals. The preparation of the 0.1000 millinormal sulfuric acid quality control standard is detailed in Section 8 of this manual. The nominal pH for this solution, ignoring any temperature or activity effects, is 4.00. Usually, the monitor is programmed to sample this solution every six or twelve hours. It is recommended that the results from the printer output be plotted on a control chart so that any long-term trends in the response can be noted. Generally, the pH results have been noted to fall in the range 3.95 to 4.05, although the range is less than this over a short period of time (e.g., several days or a week).

NOTE: Unusual values for the response generally indicate a valve problem, while long-term drifts to higher pH values generally indicate a sluggish electrode that needs rejuvenation.

Calibration of the conductivity meter is based on standards prepared from a stock solution (see Section 8). Standard pH 3.00 and 7.00 buffers are used for the pH calibration. Calibration procedures have been presented in Section 9 of this manual.

A schedule for quality control procedures is given in Figure 10-1.

Procedure	Frequency
pH calibration	weekly
conductivity calibration	weekly
quality control check	every 6 or 12 hours

Figure 10-1. Frequency of Quality Control Activities.

SECTION 11

MICROPROCESSOR OPERATION

The electronics module contains the circuit cards that perform the various functions of the sampler. Controlling all of these cards is a Z80 microprocessor operating a stored program in EPROM. This program is contained in three 2K byte EPROMs on the CPU card and is fully documented in the section called Program Flowchart (Section 14). Along with the EPROM memory, there is also one 2K byte static RAM that is used for storing and reading temporary data and variables. This RAM use has been documented in the section called RAM Memory Allocation (Section 13). Furthermore, the state of most of the RAM memory locations at power-up has been documented in the section called Microprocessor Default Values (Section 12). These sections of this manual, along with the Source Code Listing of Program (Section 15), should be referenced for an in-depth understanding of the sampler operation.

Basically, the program operates as follows: The power is applied to the system, generating a reset to the microprocessor. The microprocessor begins operation by fetching the code stored in EPROM location 0000h. (Note: addresses are shown in hexadecimal –'h'.) Thereafter, either another instruction code or data are fetched and executed, and depending on the code, the process is repeated. This process is repeated until a test condition produces the need to branch or jump to some area of the code that is not in sequence. After some more code execution, the program returns to the branch location or some other location where the process of fetching, decoding, executing, and fetching is resumed.

The software (or firmware) has been designed to use the Z80's ability to automatically vector to sections of code upon the receipt of what is known as an "interrupt." When a device interrupts, it adds the low-order 8 bits of an address to the data bus, along with the contents of the I-Register that contains the high-order 8 bits. The complete 16-bit address is forced into the program counter that controls where the next fetch occurs. This location is the start location of what is known as the interrupt service routine. At the end of these service routines is a special instruction that, when executed, causes the program to resume operation back at the location from whence it vectored (plus one).

SECTION 12

MICROPROCESSOR DEFAULT VALUES

MICRO-PROCESSOR DEFAULT VALUES

The RAM memory contains uninitalized data when power to the system is first applied, so it is necessary to load any location that will be used with what is called a default value. These defaults are listed for the locations that have significance in the program as follows:

```
PRTOUT:    set= 03h   ;start of printer message buffer set to end byte
PRTOUT:+1 to PRTOUT:+0FFh set= 00 ;rest of buffer cleared
KEYPTR:    set= 38h   ; set to point to start of KEYBUF:
KEYIN:     set= 0FFh  ; set to a non-key value
PWRUP:     set= 0FFh  ; set to indicate power has just been applied
PRTPTR:    set= PRTOUT: ; printer pointer set equal 1st location of buffer
KEYBUF:    set= 0A0h  ; eight locations set to ascii space for blanking
DISPTR:    set= 2Bh   ; set to TIME of day storage area
PHDSP:     set up to 'PH=X.XX' ; set for display pH
BLEDS:     set= 00h   ; one bit per binary led, all off at start
RAINFG:    set= 00h   ; start with not rain case, tested later
VALVES:    set= 00h   ; start with all valves off
PRTBSY:    set= 00h   ; start with printer not busy
SEQBSY:    set= 00h   ; start with no sequences in progress
RDPHFG:    set= 00h   ; start with not requesting pH sampling
QCTIME:    set= 00h   ; zero QC time
DAYS:      set= 00h   ; zero DAYS
HRS:       set= 00h   ; zero HRS
DOY:       set= 00h   ; zero DOY
DAY:       set= 00h   ;zero DAY
NOTD:      set= 00h   ; start with Not Ok To Drain set to OK
ENDPRT:    set= 00h   ; no request for end print message
BUZBIT:    set= 00h   ; set bit that controls buzzer off
PHTIME:    set= 00h   ; zero pH time counter
MAXFLG:    set= 00h   ; start with vial 01 , so not max position
PHEXTM:    set= 05h   ; DEFAULT value for pH exit time comparing
VIALCN:    set= 01(ascii) ; set to first vial position
DELPH:     set= 04(ascii) ; set to look for values within 0.04 pH
QCDEL      set= 12(ascii) ; set up to do QC sequence every 12 hours
STAID:     set= 000000(ascii) ; DEFAULT station ID
TIMOD:     set= 84(ascii) ;set to current year
```

SECTION 13

RAM MEMORY ALLOCATION

************** ACID RAIN MONITOR PROGRAM MEMORY ALLOCATION ***************

NAME	LOCATION	DESCRIPTION/USE
BOR	1800h	Beginning of RAM
STACK	1BD0h	Stack area for program
RAMPG	18h	Ram Page - high byte of RAM
CNT1	1801h	Counter 1 - storage for keyboard scan enables
MAXFLG	1802h	Max flag- set=FF when vial count= 51
BUZBIT	1803h	Buzz bit- Set=80 when buzzer is on
ENDPRT	1804h	Not used
SUMPTR	1805h	Not used
PRTSUM	1807h	Not used
DMPCTR	1808h	Not used
INCDLY	1809h	Not used
NOTD	180Ah	Not OK to Drain- set=0F or F0 if not OK
PWRUP	180Bh	Power-up- set=FF on power up, reset when time read
GOODPH	180Ch	Good pH- set=00 at start of pH reads, increments if (TEMPH-COMPH) is less than DELTApH
RDPHFG	180Dh	Read pH flag- Set=7F at start of reading, set=FF after 1st, then set=00 after a GOODPH
MSCNT	180Eh	Millisecond count- increments every 500ms.
KEYCNT	180Fh	Key count- set= number of key entries for setting
KEYIN	1810h	Key In- Keyboard key storage
NEWKEY	1811h	New Key- Used to indicate new key has been read
KEYPTR	1812h	Pointer to Keybuf location to store Keyin data
KEYOFF	1813h	Keyoff- set=FF if key is pressed, 00 if released
STCKX	1814h	Set request- set to various values for SETCKX:
DISPTR	1815h	Used with RAMPG to set HL to point to display data
BLEDS	1816h	Used to send data to binary leds on keyboard card
RAINFG	1817h	Used to honor rain condition
VALVES	1818h	Used to store state of valves 1-8
PRTBSY	1819h	Set = FF when a message is being printed
PRTPTR	181Bh	Used to point to a location in PRTOUT buffer
DLYPTR	181Dh	Used to hold next sequence location in long type
SEQBSY	181Fh	Used to indicate which sequence is in progress
TIMOD	1820h	Used to store real time from clock chip

************************** MEMORY ALLOCATION (CONT) **************************

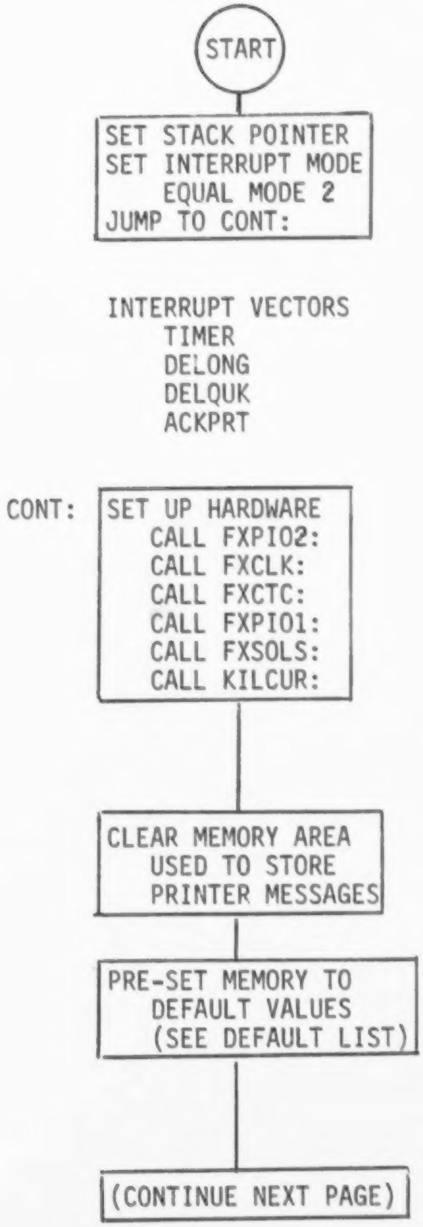
NAME	LOCATION	DESCRIPTION/USE
KEYBUF	1838h	Keyboard buffer- storage for key data
QCTIME	1840h	QC Sequence Time- storage for time to match to
DAYS	1841h	Days- used for storage of time of QC when 24hrs ormo
HRS	1842h	Hours- time of day packed data (tens,units hours)
DOY	1843h	Day of year- running total of days since power-up
DAY	1844h	Day- storage of Day of Week fro clock chip
PRTCHR	1846h	Print character- Next print character location
STOPTM	1848h	Stop time- storage for time to start ENDSEQ
STOPCK	184Ch	Stop time check- set=ff when time to check
VIALCN	184Dh	Storage for vial counter
DELPH	1850h	Storage for the delta pH allowed in measurement
QCDEL	1853h	Storage for QC delta time in hours
QDLYPTR	1856h	Used to hold address of next quick sequence
STAID	1858h	Used to store station ID
TEMPH	1860h	Used to store lattest pH reading
COMPH	1863h	Used to store the pH to comare against
TDELPH	1866h	Temporary Delta pH area for math results
MINU	1868h	Minuhend - math area storage
SUBT	186Ah	Subtrahend - math area storage
PHDSP	186Dh	Ph storage for display and printing
PHDATA	1870h	Ph data storage for display and printing
SAMVIL	1876h	Storage of vial number if another sample is pending
SECCNT	1879h	Storage for seconds during pH reading
PHTIME	187Ah	Storage for minutes during pH reading
PHEXTM	187Bh	Storage of pH exit time for comparisions
LSEQ	187Ch	Set= FF during a long sequence
;		
PRTOUT	1880h	Printer buffer 256 bytes
SUMBUF	1980h	Summary buffer - not use now

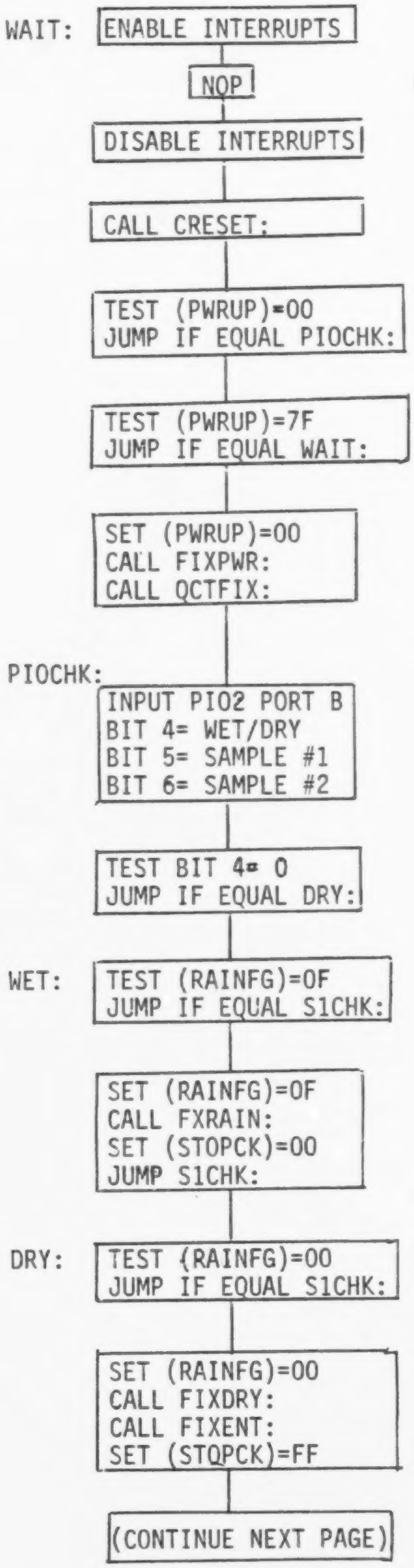
SECTION 14

PROGRAM FLOWCHART

ACID RAIN MONITOR PROGRAM FLOWCHART

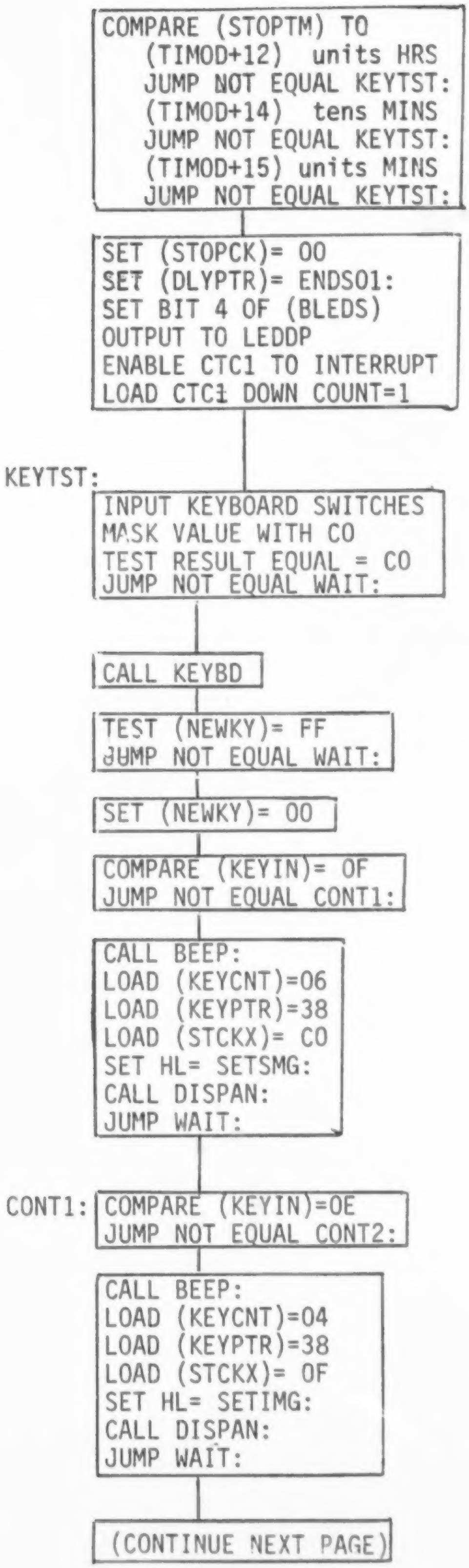
By: K. G. Kronmiller
Northrop Services, Inc.
June 30, 1985


START
SET STACK POINTER
SET INTERRUPT MODE
EQUAL MODE 2
JUMP TO CONT:
INTERRUPT VECTORS
TIMER
DELONG
DELQUK
ACKPRT
CONT:
SET UP HARDWARE
CALL FXPIO2:
CALL FXCLK:
CALL FXCTC:
CALL FXPIO1:
CALL FXSOLS:
CALL KILCUR:
CLEAR MEMORY AREA
USED TO STORE
PRINTER MESSAGES
PRE-SET MEMORY TO
DEFAULT VALUES
(SEE DEFAULT LIST)
(CONTINUE NEXT PAGE)

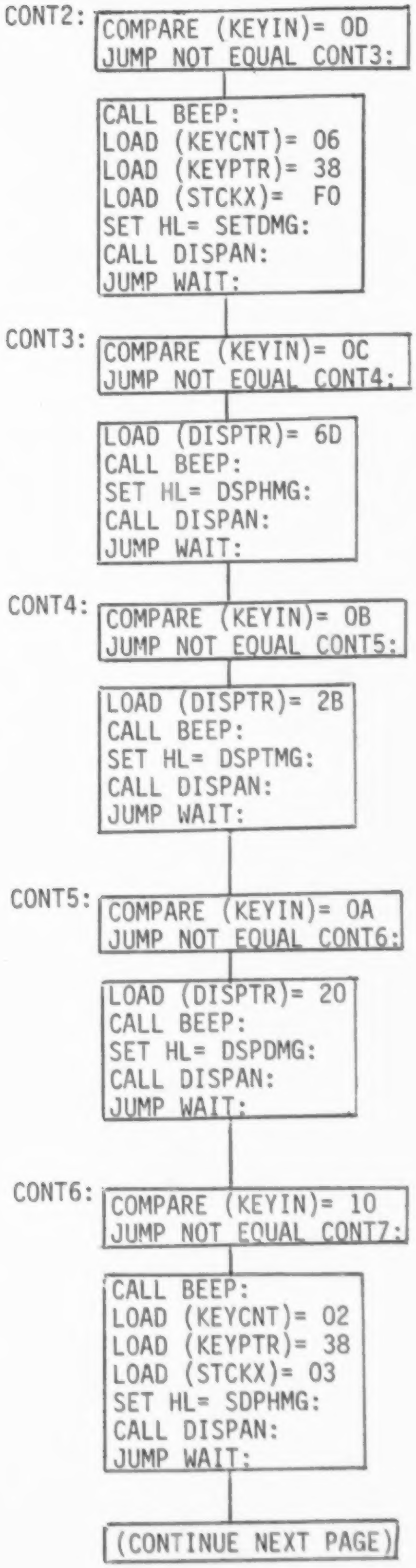

WAIT:
ENABLE INTERRUPTS
NOP
DISABLE INTERRUPTS
CALL CRESET:
TEST (PWRUP)=00
JUMP IF EQUAL PIOCHK:
TEST (PWRUP)=7F
JUMP IF EQUAL WAIT:
SET (PWRUP)=00
CALL FIXPWR:
CALL OCTFIX:
PIOCHK:
INPUT PIO2 PORT B
BIT 4= WET/DRY
BIT 5= SAMPLE #1
BIT 6= SAMPLE #2
TEST BIT 4= 0
JUMP IF EQUAL DRY:
WET:
TEST (RAINFG)=0F
JUMP IF EQUAL S1CHK:
SET (RAINFG)=0F
CALL FXRAIN:
SET (STOPCK)=00
JUMP S1CHK:
DRY:
TEST (RAINFG)=00
JUMP IF EQUAL S1CHK:
SET (RAINFG)=00
CALL FIXDRY:
CALL FIXENT:
SET (STOPCK)=FF
(CONTINUE NEXT PAGE)

(HARDWARE INTERRUPTS ARE
HONORED AND SERVICE GRANTED)

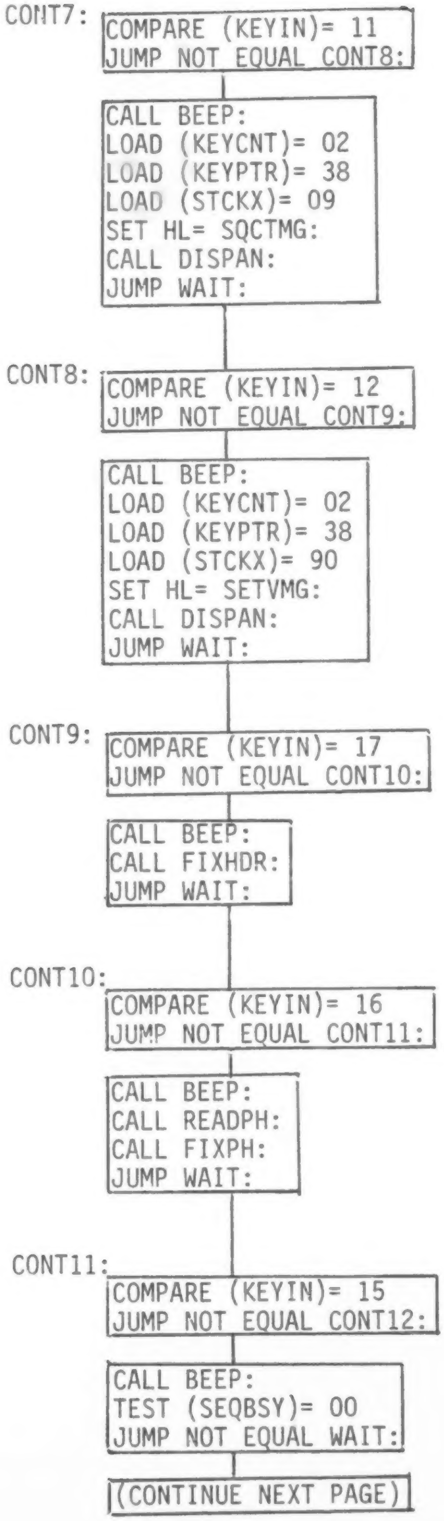
```
S1CHK:
    INPUT PIO2 PORT B
    TEST BIT 5= 0
    JUMP IF EQUAL S2CHK:
    CALL S1TRY:

S2CHK:
    INPUT PIO2 PORT B
    TEST BIT 6= 0
    JUMP IF EQUAL TSTEND:
    CALL S2TRY
    JUMP TSTEND:

TSTEND:
    TEST (PWRUP)= 00
    JUMP NOT EQUAL ENDTST:

TSTQCT:
    COMPARE (QCTIME) TO (HRS)
    JUMP NOT EQUAL ENDTST:
    COMPARE (QCTIME+1) to (DOY)
    JUMP NOT EQUAL ENDTST:

    CALL QCTFIX
    INPUT PIO2 PORT B
    TEST BIT 4= 1
    JUMP IF EQUAL ENDTST:
    TEST (SEQBSY)= 00
    JUMP NOT EQUAL ENDTST:
    TEST (NOTD)= 00
    JUMP NOT EQUAL ENDTST:
    SET BIT 2 OF (SEQBSY)= 1
    SET (DLYPTR)= QCS01:
    SET BIT 7 OF (BLEDS)
    OUTPUT TO LEDDP
    ENABLE CTC1 TO INTERRUPT
    LOAD CTC1 DOWN COUNT=1

ENDTST:
    TEST (PWRUP)= 00
    JUMP NOT EQUAL KEYTST:

    TEST (STOPCK)= 00
    JUMP IF EQUAL KEYTST:

    (CONTINUE NEXT PAGE)
```

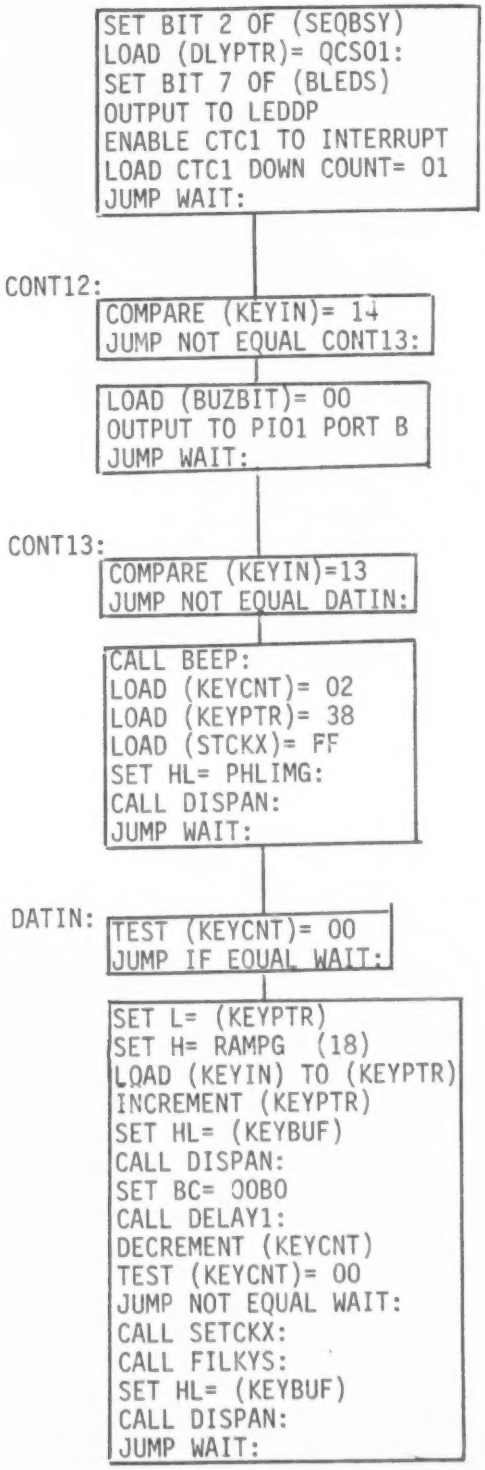


```
COMPARE (STOPTM) TO
   (TIMOD+12)  units HRS
   JUMP NOT EQUAL KEYTST:
   (TIMOD+14)  tens MINS
   JUMP NOT EQUAL KEYTST:
   (TIMOD+15) units MINS
   JUMP NOT EQUAL KEYTST:

SET (STOPCK)= 00
SET (DLYPTR)= ENDS01:
SET BIT 4 OF (BLEDS)
OUTPUT TO LEDDP
ENABLE CTC1 TO INTERRUPT
LOAD CTC1 DOWN COUNT=1

KEYTST:
INPUT KEYBOARD SWITCHES
MASK VALUE WITH C0
TEST RESULT EQUAL = C0
JUMP NOT EQUAL WAIT:

CALL KEYBD

TEST (NEWKY)= FF
JUMP NOT EQUAL WAIT:

SET (NEWKY)= 00

COMPARE (KEYIN)= 0F
JUMP NOT EQUAL CONT1:

CALL BEEP:
LOAD (KEYCNT)=06
LOAD (KEYPTR)=38
LOAD (STCKX)= C0
SET HL= SETSMG:
CALL DISPAN:
JUMP WAIT:

CONT1:
COMPARE (KEYIN)=0E
JUMP NOT EQUAL CONT2:

CALL BEEP:
LOAD (KEYCNT)=04
LOAD (KEYPTR)=38
LOAD (STCKX)= 0F
SET HL= SETIMG:
CALL DISPAN:
JUMP WAIT:

(CONTINUE NEXT PAGE)
```



```
CONT2: COMPARE (KEYIN)= 0D
       JUMP NOT EQUAL CONT3:

       CALL BEEP:
       LOAD (KEYCNT)= 06
       LOAD (KEYPTR)= 38
       LOAD (STCKX)=  F0
       SET HL= SETDMG:
       CALL DISPAN:
       JUMP WAIT:

CONT3: COMPARE (KEYIN)= 0C
       JUMP NOT EQUAL CONT4:

       LOAD (DISPTR)= 6D
       CALL BEEP:
       SET HL= DSPHMG:
       CALL DISPAN:
       JUMP WAIT:

CONT4: COMPARE (KEYIN)= 0B
       JUMP NOT EQUAL CONT5:

       LOAD (DISPTR)= 2B
       CALL BEEP:
       SET HL= DSPTMG:
       CALL DISPAN:
       JUMP WAIT:

CONT5: COMPARE (KEYIN)= 0A
       JUMP NOT EQUAL CONT6:

       LOAD (DISPTR)= 20
       CALL BEEP:
       SET HL= DSPDMG:
       CALL DISPAN:
       JUMP WAIT:

CONT6: COMPARE (KEYIN)= 10
       JUMP NOT EQUAL CONT7:

       CALL BEEP:
       LOAD (KEYCNT)= 02
       LOAD (KEYPTR)= 38
       LOAD (STCKX)= 03
       SET HL= SDPHMG:
       CALL DISPAN:
       JUMP WAIT:

       (CONTINUE NEXT PAGE)
```


CONT7:
COMPARE (KEYIN)= 11
JUMP NOT EQUAL CONT8:
CALL BEEP:
LOAD (KEYCNT)= 02
LOAD (KEYPTR)= 38
LOAD (STCKX)= 09
SET HL= SQCTMG:
CALL DISPAN:
JUMP WAIT:
CONT8:
COMPARE (KEYIN)= 12
JUMP NOT EQUAL CONT9:
CALL BEEP:
LOAD (KEYCNT)= 02
LOAD (KEYPTR)= 38
LOAD (STCKX)= 90
SET HL= SETVMG:
CALL DISPAN:
JUMP WAIT:
CONT9:
COMPARE (KEYIN)= 17
JUMP NOT EQUAL CONT10:
CALL BEEP:
CALL FIXHDR:
JUMP WAIT:
CONT10:
COMPARE (KEYIN)= 16
JUMP NOT EQUAL CONT11:
CALL BEEP:
CALL READPH:
CALL FIXPH:
JUMP WAIT:
CONT11:
COMPARE (KEYIN)= 15
JUMP NOT EQUAL CONT12:
CALL BEEP:
TEST (SEQBSY)= 00
JUMP NOT EQUAL WAIT:
(CONTINUE NEXT PAGE)



```
          SET BIT 2 OF (SEQBSY)
          LOAD (DLYPTR)= QCS01:
          SET BIT 7 OF (BLEDS)
          OUTPUT TO LEDDP
          ENABLE CTC1 TO INTERRUPT
          LOAD CTC1 DOWN COUNT= 01
          JUMP WAIT:

CONT12:   COMPARE (KEYIN)= 14
          JUMP NOT EQUAL CONT13:

          LOAD (BUZBIT)= 00
          OUTPUT TO PIO1 PORT B
          JUMP WAIT:

CONT13:   COMPARE (KEYIN)=13
          JUMP NOT EQUAL DATIN:

          CALL BEEP:
          LOAD (KEYCNT)= 02
          LOAD (KEYPTR)= 38
          LOAD (STCKX)= FF
          SET HL= PHLIMG:
          CALL DISPAN:
          JUMP WAIT:

DATIN:    TEST (KEYCNT)= 00
          JUMP IF EQUAL WAIT:

          SET L= (KEYPTR)
          SET H= RAMPG  (18)
          LOAD (KEYIN) TO (KEYPTR)
          INCREMENT (KEYPTR)
          SET HL= (KEYBUF)
          CALL DISPAN:
          SET BC= 00B0
          CALL DELAY1:
          DECREMENT (KEYCNT)
          TEST (KEYCNT)= 00
          JUMP NOT EQUAL WAIT:
          CALL SETCKX:
          CALL FILKYS:
          SET HL= (KEYBUF)
          CALL DISPAN:
          JUMP WAIT:
```

***** END IN-LINE CODE *****

***** SUBROUTINES *****
(ALPHABETICAL ORDER)

SUBROUTINE NAME: ABQCSQ: (ABORT QC SEQUENCE MESSAGE PREPARATION)
DESCRIPTION: MOVE ABORQC: MESSAGE TO PRTOUT: BUFFER, UPDATE PRTPTR, CALL TSTBSY: TO START PRINTER

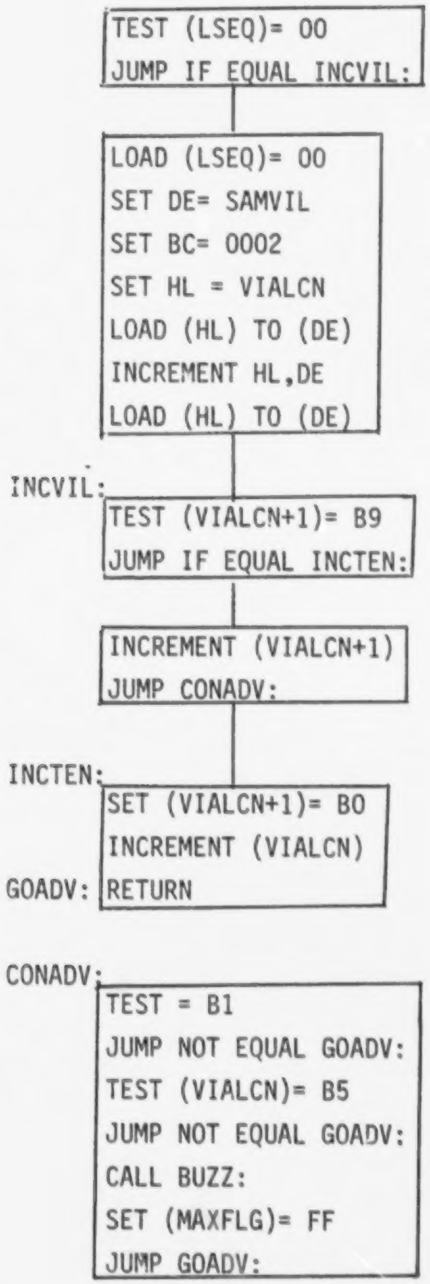
```
ABQCSQ:
    SET BC= 00FF
    SET DE= (PRTPTR)
    SET HL= ABORQC:
    CALL MOVDAT:
    SET (PRTPTR)= DE
    CALL TSTBSY:
    RETURN
```

SUBROUTINE NAME: ADVVIL: (ADVANCE THE VIAL CAROUSEL)
DESCRIPTION: SEND ADVANCE CAROUSEL SIGNAL TO CAROUSEL, DELAY A WHILE, REMOVE SIGNAL, SAVE OLD VIAL COUNT IF ITS A LONG SEQUENCE, INCREMENT VIAL COUNT, SEE IF COUNT IS 51, IF SO TURN ON BUZZER, SET MAXFLG:= FF

```
ADVVIL:
    OR (BUZBIT) WITH 40
    OUTPUT TO PIO2 PORT B
    SET BC= 0060
    CALL DELAY1:
    OR (BUZBIT) WITH 00
    OUTPUT TO PIO2 PORT B
```

(CONTINUE NEXT PAGE)

ADVVIL: (CONT)



```
        TEST (LSEQ)= 00
        JUMP IF EQUAL INCVIL:

        LOAD (LSEQ)= 00
        SET DE= SAMVIL
        SET BC= 0002
        SET HL = VIALCN
        LOAD (HL) TO (DE)
        INCREMENT HL,DE
        LOAD (HL) TO (DE)

INCVIL: TEST (VIALCN+1)= B9
        JUMP IF EQUAL INCTEN:

        INCREMENT (VIALCN+1)
        JUMP CONADV:

INCTEN: SET (VIALCN+1)= B0
        INCREMENT (VIALCN)
GOADV:  RETURN

CONADV: TEST = B1
        JUMP NOT EQUAL GOADV:
        TEST (VIALCN)= B5
        JUMP NOT EQUAL GOADV:
        CALL BUZZ:
        SET (MAXFLG)= FF
        JUMP GOADV:
```

SUBROUTINE NAME: BEEP: (BEEP THE BUZZER FOR ATTENTION)
DESCRIPTION: SET THE BUZBIT HIGH, OUTPUT THEN RESET

```
BEEP:
    OUTPUT 80 TO PIO1 PORT B
    SET BC= 0AFF
    CALL DELAY1:
    OUTPUT 00 TO PIO1 PORT B
    RETURN
```

SUBROUTINE NAME: BUZZ: (BUZZ TO BUZZER CONTINEOUS)

```
BUZZ:
    OUTPUT 80 TO PIO1 PORT B
    SET (BUZBIT)= 80
    RETURN
```

SUBROUTINE NAME: CRESET: (CLOCK INTERRUPT RESET)
DESCRIPTION: READ THE CLOCK CHIP INTERRUPT REG. THREE TIMES

```
CRESET:
    CALL FIXIN:
    SET A= CKINT
    CALL READCK:
    CALL READCK:
    CALL READCK:
    RETURN
```

SUBROUTINE NAME: DECSUB: (DECIMAL SUBTRACT)

DESCRIPTION: SUBTRACT (SUBT) FROM (MINU) LOCATIONS, HL POINTS TO (MINU), DE POINTS TO (SUBT)

```
DECSUB:
        EXCHANGE DE,HL
        SET CARRY FLAG
DCSB1:  SET A= 99
        ADD WITH CARRY 00
        SUBTRACT WITH CARRY (HL)
        EXCHANGE DE,HL
        ADD WITH CARRY (HL)
        DECIMAL ADJUST A
        EXCHANGE DE,HL
        LOAD A TO (HL)
        INCREMENT HL, AND DE
        DECREMENT COUNT IN C
        TEST C= 00
        JUMP NOT EQUAL DCSB1:
        COMPLIMENT CARRY FLAG
        RETURN
```

SUBROUTINE NAME: DELAY1: (DELAY ROUTINE)

DESCRIPTION: BC CONTAINS VALUE TO DECREMENT

```
DELAY1:
        DECREMENT C COUNT
        TEST C= 00
        JUMP NOT EQUAL DELAY1:
        COMPARE B COUNT TO 00
        JUMP IF EQUAL GODLY1:
        DECREMENT B COUNT
        JUMP DELAY1:
```

SUBROUTINE NAME: DISPAN (DISPLAY TO 8- CHARACTER DISPLAY)

```
DISPAN:
       SET BC= 0807
LOPDIS LOAD A= CHARACTER
       OUTPUT TO DISPLAY
       INCREMENT POINTER
       DECREMENT COUNTER
       JUMP NOT ZERO LOPDIS:
       OUTPUT TO LED'S
       RETURN
```

SUBROUTINE NAME: FILKYS (FILL KEY BUFFER AREA WITH BLANKS)

```
FILKYS:
       LOAD (KEYBUF)= A0
       RETURN
```

SUBROUTINE NAME: FIXEND: (PREPARE RAIN OVER MESSAGE FOR PRINTER)

```
FIXEND:
       MOVE MESSAGE TO (PRTOUT)
       CALL TSTBSY:
       RETURN
```

SUBROUTINE NAME: FIXENT: (ADD 1 HOUR TO TIME, STORE IN (STOPTM))

```
FIXENT:
       INCREMENT UNITS OF HOURS
       STORE (STOPTM)
       RETURN
```

SUBROUTINE NAME: FIXHDR: (MOVE HEADER INFO TO (PRTOUT))

```
FIXHDR:
        MOVE DATA TO (PRTOUT)
        CALL  TSTBSY:
        RETURN
```

SUBROUTINE NAME: FIXIN: (SET PIO2 PORT B LOW 4 BIT AS INPUT)

```
FIXIN:
        OUTPUT MODE 3 TO PIO
        OUTPUT FF TO PORT B
        RETURN
```

SUBROUTINE NAME: FIXOUT: (SET PIO2 PORT B LOW 4 BITS AS OUTPUT)

```
FIXOUT:
        OUTPUT MODE 3 TO PIO
        OUTPUT FO TO PORT B
        RETURN
```

SUBROUTINE NAME: FIXPH: (MOVE PH MESSAGE TO (PRTOUT))

```
FIXPH:
        MOVE DATA TO (PRTOUT)
        CALL  TSTBSY:
        RETURN
```

SUBROUTINE NAME: FIXPWR: (MOVE POWER-UP MESSAGE TO (PRTOUT))

```
FIXPWR:
        MOVE DATA TO (PRTOUT)
        CALL  TSTBSY:
        RETURN
```

```
SUBROUTINE NAME:  FXPI02:  (PREPARE PI02 FOR OPERATION)
                    FXPI02:
                          SEND MODE 3 TO PI02 PORT A
                          SEND 00 TO PORT A
                          SEND MODE 3 TO PI02 PORT B
                          SEND FF TO PORT B
                          RETURN
```

```
SUBROUTINE NAME:  FXRAIN:  (MOVE RAIN ON MESSAGE TO (PRTOUT))
                    FXRAIN:
                          MOVE MESSAGE TO (PRTOUT)
                          CALL  TSTBSY:
                          RETURN
```

```
SUBROUTINE NAME:  FIXDRY:  (MOVE RAIN OFF MESSAGE TO (PRTOUT))
                    FIXDRY:
                          MOVE MESSAGE TO (PRTOUT)
                          CALL  TSTBSY:
                          RETURN
```

```
SUBROUTINE NAME:  FXSOLS:  (SEND OFF TO ALL VALVES)
                    FXSOLS:
                          LOAD (VALVES)= 00
                          SEND 00 TO SOLPD
                          RETURN
```

```
SUBROUTINE NAME:  FXVIAL:  (MOVE VIAL AND PH MESSAGE TO (PRTOUT))
                    FXVIAL:
                          MOVE MESSAGE TO (PRTOUT)
                          CALL  TSTBSY:
                          RETURN
```

SUBROUTINE NAME: KEYBD: (SCAN KEYBOARD FOR SWITCH CLOSURE)

```
KEYBD:
        SEND COLUMN ENABLE
        INPUT ROW DATA
        IF NOT COLSURE FOUND,
          SEND NEXT COLUMN ENABLE
        DECODE KEY IF FOUND
        COMPARE TO LAST KEY
        IF NOT EQUAL, STORE (KEYIN)
        SET (KEYOFF)= FF
        RETURN
```

SUBROUTINE NAME: KILCUR: (SEND DISABLES TO DISPLAY CURSOR MEMORY)

```
KILCUR:
        SEND CLEARS TO CURSOR
        RETURN
```

SUBROUTINE NAME: MOVDAT: (MOVE DATA FROM MEMORY TO RAM)

```
MOVDAT:
        MOVE DATA FORM (HL) TO (DE)
        COMPARE TO 03 END CHARACTER
        REPEAT UNTIL 03
        RETURN
```

SUBROUTINE NAME: NOPHFX: (MOVE NO PH MESSAGE TO (PRTOUT))

```
NOPHFX:
        MOVE MESSAGE TO (PRTOUT)
        CALL  TSTBSY:
        RETURN
```

SUBROUTINE NAME: PACKDE: (PACK DELTA PH INTO ONE MEMORY LOACTION)

```
PACKDE:
        ADD DELPH TO DELPH+1
        STORE IN (TDELPH)
        RETURN
```

SUBROUTINE NAME: PACKPH: (PACK THE PH INTO TWO LOCATIONS)

```
PACKPH:
        ADD TWO LSD OF PH
        STORE IN (TEMPH)
        STORE MSD PH IN (TEMPH+1)
        RETURN
```

SUBROUTINE NAME: QCTFIX: (ADD DELTAQC TIME TO REAL TIME, STORE TO QCTIME)

```
QCTFIX:
        ADD QCDELT TO REAL TIME
        STORE TO QCTIME
        RETURN
```

SUBROUTINE NAME: RDYPH: (SET FLAGS TO ENABLE LOOKS AT PH)

```
RDYPH:
        LOAD (RDPHFG)= 7F
        LOAD (PHTIME)= 00
        LOAD (SECCNT)= 00
        RETURN
```

SUBROUTINE NAME: READCK: (READ THE CLOCK CHIP REGISTER)

```
READCK:
        SEND CHIP SIGNALS TO ENABLE
        INPUT DATA
        MASK OFF HIGH BYTE
        RETURN
```

```
SUBROUTINE NAME:  READPH:  ( READ THE PH METER FOR LATTEST DATA)
                    READPH:
                          INPUT THREE DIGITS FROM METER
                          STORE AT (PHDATA)
                          RETURN
```

```
SUBROUTINE NAME:  SENDCK:  (SEND DATA TO CLOCK CHIP TO SET)
                    SENDCK:
                          SEND ENABLE SIGNALS TO CLOCK
                          SEND DATA
                          SEND DISABLES
                          RETURN
```

```
SUBROUTINE NAME:  SETCKX:  (USE KEY DATA TO SET VARIABLE LOCATIONS)
                    SETCKX:
                          DECODE (STCKX) TO BRANCH
                          USE DATA AT (KEYBUF) FOR INPUT
                          SET PHEXTM IF REQ'D
                          SET VIALCN  "  "
                          SET QCDEL   "  "
                          SET DELPH   "  "
                          SET STAID   "  "
                          SET DATE    "  "
                          SET TIME    "  "
                          SET (STCKX)= 00
                          RETURN
```

SUBROUTINE NAME: S1TRY: (SAMPLE SIDE 1 READY, TRY TO START SEQUENCE)

```
S1TRY:
        TEST (NOTD)= 00
        RETURN NOT EQUAL 00
        TEST (SEQBSY) BIT 0
        JUMP SAM1QK: IF SET
        TEST (SEQBSY) BIT 1
        JUMP SAM1QK: IF SET
        TEST (SEQBSY) BIT 2
        CALL TERMQC: IF SET
S1LONG:
        SET (SEQBSY) BIT 0
        SET (NOTD) = 0F
        SET (LSEQ) = FF
        LIGHT LED FOR SEQ1
        SWITCH DIRECTION FILL VALVE
        START SEQUENCE 1
        RETURN
SAM1QK:
        SET (NOTD)= 0F
        SWITCH DIRECTION FILL VALVE
        START QUICK S1 SEQUENCE
        RETURN
```

SUBROUTINE NAME: S2TRY: (SAMPLE SIDE 2 READY, TRY TO START SEQUENCE)

```
S2TRY:
        TEST (NOTD) = 00
        RETURN NOT EQUAL 00
        TEST (SEQBSY) BIT 0
        JUMP SAM2QK: IF SET
        TEST (SEQBSY) BIT 1
        JUMP SAM2QK: IF SET
        TEST (SEQBSY) BIT 2
        CALL  TERMQC: IF SET
S2LONG:
        SET (SEQBSY) BIT 1
        SET (NOTD)= F0
        SET (LSEQ)= FF
        LIGHT LED FOR SEQ 2
        SWITCH DIRECTION FILL VALVE
        START SEQUENCE 2
        RETURN
SAM2QK:
        SET (NOTD)= F0
        SWITCH DIRECTION FILL VALVE
        START QUICK S2 SEQUENCE
        RETURN
```

SUBROUTINE NAME: TERMQC: (TERMINATE QC SEQUENCE IF NECESSARY)

```
TERMQC:
        CALL ABQCSQ:
        RESET BIT 2 OF (SEQBSY)
        OFF LED FOR QC SEQUENCE
        DISABLE CTC CH1
        RETURN
```

SUBROUTINE NAME: TSTBSY: (TEST FOR PRINTER BUSY)

```
TSTBSY:
        TEST (PRTBSY)= FF
        RETURN IF EQUAL
        OUTPUT 1ST CHARACTER IN (PRTOUT)
        SET (PRTBSY)= FF
        INCREMENT (PRTCHR) POINTER
        RETURN
```

*********** INTERRUPT SERVICE ROUTINES ***********

TIMER: AFTER THE CLOCK CHIP IS INITIALIZED, THE 500ms INTERRUPT SIGNALS ARE DOWN COUNTED BY THE CTC CHO CAUSING AN INTERRUPT AND BRANCH TO TIMER: ROUTINE. EVERY OTHER ONE (1 PER SECOND) THE CLOCK TIME IS READ AND STORED. OTHER TESTS ARE PERFORMED AT THIS TIME AS REQUIRED.

```
TIMER:
    READ CLOCK INTERRUPT REG.
    READ CLOCK INTERRUPT REG.
    READ CLOCK INTERRUPT REG.
    INCREMENT (MSCNT)
    TEST BIT 0 OF (MSCNT)
    RETURN IF NOT SET
CONTIM:
    CALL FIXIN:
    READ CLOCK TENTHS
    READ CLOCK UNITS OF SEC.
    READ CLOCK TENS OF SEC.
    READ CLOCK UNITS MIN.
    READ CLOCK TENS MIN.
    READ CLOCK UNITS HOURS
    READ CLOCK TENS HOURS
    READ CLOCK UNITS MONTHS
    READ CLCOK TENS MONTHS
    READ CLOCK UNITS OF YEARS
    READ TENTHS SEC AGAIN
    COMPARE TO FIRST READ
    JUMP NOT EQUAL CONTIM:
    PACK TENS AND UNITS OF HOURS
        INTO (HRS)
```

(CONTINUE NEXT PAGE)

TIMER: CONT

```
        READ CLOCK DAY OF WEEK
        COMPARE TO (DAY)
        JUMP IF EQUAL TESPW:
        TEST (PWRUP)=00
        JUMP NOT EQUAL TESPW:
        LOAD NEW DAY IN (DAY)
        INCREMENT (DOY)
        CALL  FIXHDR:

TESPW:
        RESET BIT 7 OF (PWRUP)
        CALL READPH:
        CALL  PACKPH:
        CALL  PACKDE:
        TEST (READPH)= 00
        JUMP IF EQUAL TSTSWS:
        TEST BIT 7 OF (RDPHFG)
        JUMP IF SET TSTMPH:
        SET BIT 7 OF (RDPHFG)
        SET (SECCNT)= 00
        SET (PHTIME)= 00

MOVPH:
        MOVE (TEMPH) TO (COMPH)
        SET (GOODPH)= 00
        JUMP TSTSWS:

TSTMPH:
        INCREMENT (SECCNT)
        TEST EQUAL 60
        JUMP NOT EQUAL COMPAR:
        SET (SECCNT)= 00
        INCREMENT (PHTIME)
        COMPARE EQUAL (PHEXTM)
        JUMP NOT EQUAL COMPAR:
        SET (RDPHFG)= 00
        START CTC CH1 AGAIN TO
            FINISH SEQUENCE
        JUMP TSTSWS:
```

(CONTINUE NEXT PAGE)

```
TIMER: CONT
    COMPAR:
        TEST (SECCNT)= 10
        JUMP NOT EQUAL TSTSWS:
        MOVE (COMPH) TO (MINU)
        MOVE (TEMPH) TO (SUBT)
        CALL DECSUB:
        JUMP NO CARRY OKDEL:
    NOTOK:
        MOVE (TEMPH) TO (MINU)
        MOVE (COMPH) TO (SUBT)
        CALL DECSUB:
    OKDEL:
        MOVE (TDELPH) TO (MINU)
        LOAD (MINU+1)==00
        CALL DECSUB:
        JUMP IF CARRY MOVPH:
        INCREMENT (GOODPH)
        TEST (GOODPH)= 03
        JUMP NOT EQUAL TSTSWS:
        ENABLE CTC CH1 to CONTINUE
        SET (RDPHFG) = 00
        SET (PHTIME) = 00
    TSTSWS:
        READ KEYBOARD SWITCHES
        TEST BIT 7
        JUMP IF SET BLKDSP:
        TEST BIT 6
        JUMP IF SET SHODSP:
        JUMP ENDSCK:
    BLKDSP:
        LOAD HL= BLKDSP:
        CALL DISPAN:
        JUMP ENDSCK:
    SHODSP:
        LOAD HL= (DISPTR)
        CALL DISPAN:
    ENDSCK:
        RETI
```

************ INTERRUPT SERVICE ROUTINE ************

DELONG: THE ONCE PER 500ms SIGNAL FROM THE OUTPUT OF CTC CH0 IS CONNECTED TO THE INPUT OF CTC CH1 FOR DOWN COUNTING TO OBTAIN VARIABLE DELAYS IN THE LONG SEQUENCES. WHEN THE TIME OUT OCCURS, THE VALUE STORED IN (DLYPTR) IS LOADED INTO THE IX REGISTER AND A JUMP IX INSTRUCTION IS EXECUTED TO CONTINUE THE SERVICE ROUTINE AT ONE OF THE SEQUENCES. EACH SEQUENCE ENDS IN THE SETTING OF (DLYPTR) TO THE NEXT STEP IN THE SEQUENCE AND THE RE-STARTING OF THE DOWN COUNTER.

```
DELONG:
    SEND DISABLE TO CTC1
    LOAD IX FROM (DLYPTR)
    JUMP (IX)
```

(NOTE: RETURN FROM INTERRUPT
IS LOCATED AT THE END OF
EACH STEP IN THE SEQUENCE.)

*************** INTERRUPT SERVICE ROUTINE ***************

DELQUK: THE ONCE PER 500ms SIGNAL FROM THE OUTPUT OF CTC CH0 IS CONNECTED TO THE INPUT OF CTC CH2 FOR DOWN COUNTING TO OBTAIN VARIABLE DELAYS IN THE QUICK SEQUENCES. WHEN THE TIME OUT OCCURS, THE VALUE STORED IN (QDLYPTR) IS LOADED INTO THE IY REGISTER AND A JUMP (IY) INSTRUCTION IS EXECUTED TO CONTINUE THE SERVICE ROUTINE AT ONE OF THE SEQUENCES. EACH STEP IN THE SEQUENCE ENDS BY SETTING (QDLYPTR) TO POINT TO THE NEXT STEP IN THE SEQUENCE AND THE RE-STARTING OF THE CTC DOWN COUNTER CH2.

```
DELQUK:
        SEND DISABLE TO CTC CH2
        LOAD IY FROM (QDLYPTR)
        JUMP (IY)
```

(NOTE: RETURN FROM INTERRUPT
IS LOCATED AT THE END OF
EACH STEP IN THE SEQUENCES.)

************ INTERRUPT SERVICE ROUTINE *************

ACKPRT: THE ACKNOWLEDGE SIGNAL FROM THE ALPS PRINTER IS INPUT TO CTC CH3. THE DOWN COUNT TO ZERO FROM ONE CAUSES A BRANCH TO THIS SERVICE ROUTINE, WHERE THE NEXT CHARACTER IN THE PRINTER BUFFER (PRTOUT) IS CHECKED FOR THE END AND IF NOT, IT IS SENT TO THE PRINTER. IF THE END CHARACTER IS DETECTED, THE POINTERS AND FLAGS ARE RESET, ENDING THE PRINT.

```
ACKPRT:
        TEST CHARACTER POINTED TO
            BY (PRTCHR) = 03
        JUMP IF EQUAL DONEP:
        SEND CHARACTER TO PRINTER
        INCREMENT (PRTCHR) POINTER
EXPRT:
        RETI
DONEP:
        SET (PRTPTR)= PRTOUT:
        SET (PRTCHR)= PRTOUT:
        SET (PRTBSY)= 00
        JUMP EXPRT:
```

*********** VALVE OPERATION SEQUENCES **********

THER ARE WHAT IS KNOWN AS LONG SEQUENCES AND QUICK SEQUENCES TO HANDLE THE NEED TO STORE RAIN IN VIALS AND PERFORM THE PH DETERMINATION OR TO JUST STORE RAIN IN VIALS IN CASE THE PH CHAMBER IS BUSY WITH A PERVIOUS SAMPLE. THE LONG SEQUENCES ARE CHAINED VIA INTERRUPTS FROM CTC CH1 WITH JUMPS VIA (IX), AND THE QUICK SEQUENCES ARE CHAINED VIA INTERRUPTS FROM CTC CH2 WITH JUMPS VIA (IY). FUTHERMORE, THERE IS A SEQUENCE TO PERFORM THE QC SEQUENCE (QUALITY CONTROL) WHICH USES CTC CH1 INTERRUPTS AND JUMPS VIA (IX), AND AN END SEQUENCE TO DRAIN THE LEFT OVER RAIN FROM THE SAMPLE ACCUMULATORS AFTER THE COVER CLOSES WHICH ALSO USES INTERRUPTS FROM CTC CH1 AND JUMPS VIA (IX).

LONG SEQUENCE - SAMPLE SIDE 1

```
S1S01: LOAD IX= S1S02:
       LOAD (DLYPTR)= (IX)
       SEND OPEN DRAIN VALVE
       ENABLE CTC1 TO INTERRUPT
       LOAD DOWN COUNT= 16 (8SEC)
       RETI

S1S02: LOAD IX= S1S03:
       LOAD (DLYPTR)= (IX)
       SEND OPEN DRAIN VALVE
            OPEN DISTILLED VALVE

       ENABLE CTC1 TO INTERRUPT
       LOAD DOWN COUNT= 06 (3SEC)
       RETI

S1S03: LOAD IX= S1S04:
       LOAD (DLYPTR)= (IX)
       SEND OPEN DRAIN VALVE
            OPEN SAMP1 VALVE
            CLOSE DISTILLED VALVE
       ENABLE CTC1 TO INTERRUPT
       LOAD DOWN COUNT= 12 (6SEC)
       RETI
```

LONG SEQUENCE - SAMPLE SIDE 1 (CONT)

```
S1S04: LOAD IX= S1S05:
       LOAD (DLYPTR)= (IX)
       SEND OPEN PH DIRECTION VALVE
            OPEN SAMP1 VALVE
            CLOSE DRAIN VALVE
       ENABLE CTC1 TO INTERRUPT
       LOAD DOWN COUNT= 08 (4SEC)
       RETI

S1S05: LOAD IX= S1S06:
       LOAD (DLYPTR)= (IX)
       SEND OPEN PH DIRECTION VALVE
            OPEN SAMP1 VALVE
            CLOSE DRAIN VALVE
       ENABLE CTC1 TO INTERRUPT
       LOAD DOWN COUNT= 16 (8SEC)
       RETI

S1S06: LOAD IX= S1S07:
       LOAD (DLYPTR)= (IX)
       SEND CLOSE ALL VALVES
       CALL ADVVIL:
       ENABLE CTC1 TO INTERRUPT
       LOAD DOWN COUNT= 06 (3SEC)
       RETI

S1S07: LOAD IX= S1S08:
       LOAD (DLYPTR)= (IX)
       SET (NOTD)= 00
       CALL RDYPH:
       RETI__________(NOTE: TIMER: WILL RE-
                      START INTERRUPTS)
```

(CONTINUE NEXT PAGE)

LONG SEQUENCE - SAMPLE SIDE 1 (CONT)

```
S1S08: LOAD IX= S1S09:
       LOAD (DLYPTR)= (IX)
       CALL FXVIAL:
       SEND OPEN DRAIN VALVE
       ENABLE CTC1 TO INTERRUPT
       LOAD DOWN COUNT= 16 (8SEC)
       RETI

S1S09: LOAD IX= S1S10:
       LOAD (DLYPTR)= (IX)
       SEND OPEN KCL VALVE
            CLOSE DRAIN VALVE
       ENABLE CTC1 TO INTERRUPT
       LOAD DOWN COUNT= 06 (3SEC)
       RETI

S1S10: LOAD IX= S1S11:
       LOAD (DLYPTR)= (IX)
       SEND OFF ALL VALVES
       SET (SEQBSY) BIT 0= 0
       TURN OFF SEQ1 LED
       RETI

S1S11: RETI
```

LONG SEQUENCE - SAMPLE SIDE 2

```
S2S01: LOAD IX= S2S02:
       LOAD (DLYPTR)= (IX)
       SEND OPEN DRAIN VALVE
       ENABLE CTC1 TO INTERRUPT
       LOAD DOWN COUNT= 16 (8SEC)
       RETI

S2S02: LOAD IX= S2S03:
       LOAD (DLYPTR)= (IX)
       SEND OPEN DRAIN VALVE
            OPEN DISTILLED VALVE
       ENABLE CTC1 TO INTERRUPT
       LOAD DOWN COUNT= 06 (3SEC)
       RETI

S2S03: LOAD IX= S2S04:
       LOAD (DLYPTR)= (IX)
       SEND OPEN DRAIN VALVE
            OPEN SAMP2 VALVE
            CLOSE DISTILLED VALVE
       ENABLE CTC1 TO INTERRUPT
       LOAD DOWN COUNT= 12 (6SEC)
       RETI

S2S04: LOAD IX= S2S05:
       LOAD (DLYPTR)= (IX)
       SEND OPEN PH DIRECTION VALVE
            OPEN SAMP2 VALVE
            CLOSE DRAIN VALVE
       ENABLE CTC1 TO INTERRUPT
       LOAD DOWN COUNT= 08 (4SEC)
       RETI
```

LONG SEQUENCE - SAMPLE SIDE 2 (CONT)

```
S2S05: LOAD IX= S2S06:
       LOAD (DLYPTR)= (IX)
       SEND OPEN PH DIRECTION VALVE
            OPEN SAMP2 VALVE
            CLOSE DRAIN VALVE
       ENABLE CTC1 TO INTERRUPT
       LOAD DOWN COUNT= 16 (8SEC)
       RETI

S2S06: LOAD IX= S2S07:
       LOAD (DLYPTR)= (IX)
       SEND CLOSE ALL VALVES
       CALL ADVVIL:
       ENABLE CTC1 TO INTERRUPT
       LOAD DOWN COUNT= 06 (3SEC)
       RETI

S2S07: LOAD IX= S2S08:
       LOAD (DLYPTR)= (IX)
       SET (NOTD)= 00
       CALL RDYPH:
       RETI          (NOTE: TIMER: WILL
                      RE-START INTERRUPTS)
S2S08: LOAD IX= S2S09:
       LOAD (DLYPTR)= (IX)
       CALL FXVIAL:
       SEND OPEN DRAIN VALVE
       ENABLE CTC1 TO INTERRUPT
       LOAD DOWN COUNT= 16 (8SEC)
       RETI
```

LONG SEQUENCE - SAMPLE SIDE 2 (CONT)

```
S2S09: LOAD IX= S2S10:
       LOAD (DLYPTR)= (IX)
       SEND OPEN KCL VALVE
            CLOSE DRAIN VALVE
       ENABLE CTC1 TO INTERRUPT
       LOAD DOWN COUNT= 06 (3SEC)
       RETI

S2S10: LOAD IX= S2S11:
       LOAD (DLYPTR)= (IX)
       SEND OFF ALL VALVES
       SET (SEQBSY) BIT 1 = 0
       TURN OFF SEQ2 LED
       RETI

S2S11: RETI
```

QUICK SEQUENCE - SAMPLE SIDE 1

```
S1QS01: LOAD IY= S1QS02:
        LOAD (QDLYPTR)= (IY)
        SEND OPEN SAMP1 VALVE
        ENABLE CTC2 TO INTERRUPT
        LOAD DOWN COUNT= 24 (12SEC)
        RETI

S1QS02: LOAD IY= S1QS03:
        LOAD (QDLYPTR)= (IY)
        SEND CLOSE SAMP1 VALVE
        CALL NOPHFX:
        CALL ADVVIL:
        ENABLE CTC2 TO INTERRUPT
        LOAD DOWN COUNT= 06 (3SEC)
        RETI

S1QS03: SET (NOTD)= 00
        RETI
```

QUICK SEQUENCE - SAMPLE SIDE 2

```
S2QS01: LOAD IY= S2QS02:
        LOAD (QDLYPTR)= (IY)
        SEND OPEN SAMP2 VALVE
        ENABLE CTC2 TO INTERRUPT
        LOAD DOWN COUNT= 24 (12SEC)
        RETI

S2QS02: LOAD IY= S2QS03:
        LOAD (QDLYPTR)= (IY)
        SEND CLOSE SAMP2 VALVE
        CALL NOPHFX:
        CALL ADVVIL:
        ENABLE CTC2 TO INTERRUPT
        LOAD DOWN COUNT= 06 (3SEC)
        RETI
```

QUICK SEQUENCE - SAMPLE SIDE 2 (CONT)

```
S2QS03: SET (NOTD)= 00
        RETI
```

END SEQUENCE

```
ENDS01: LOAD IX= ENDS02:
        LOAD (DLYPTR)= (IX)
        SEND OPEN SAMP1 and SAMP2 VALVES
        ENABLE CTC1 TO INTERRUPT
        LOAD DOWN COUNT= 20 (10SEC)
        RETI

ENDS02: LOAD IX= ENDS03:
        LOAD (DLYPTR)= (IX)
        SEND OFF ALL VALVES
        CALL FIXEND:
        CALL ADVVIL:
        ENABLE CTC1 TO INTERRUPT
        LOAD DOWN COUNT= 06 (3SEC)
        RETI

ENDS03: TURN OFF END SEQ. LED
        RETI
```

QC SEQUENCE

```
QCS01:  LOAD IX= QCS02:
        LOAD (DLYPTR)= (IX)
        SEND OPEN DRAIN VALVE
        ENABLE CTC1 TO INTERRUPT
        LOAD DOWN COUNT= 24 (12SEC)
        RETI

QCS02:  LOAD IX= QCS03:
        LOAD (DLYPTR)= (IX)
        SEND OPEN DRAIN VALVE
             OPEN DISTILLED VALVE
        ENABLE CTC1 TO INTERRUPT
        LOAD DOWN COUNT= 06 (3SEC)
        RETI

QCS03:  LOAD IX= QCS04:
        LOAD (DLYPTR)= (IX)
        SEND OPEN DRAIN VALVE
             CLOSE DISTILLED VALVE
        ENABLE CTC1 TO INTERRUPT
        LOAD DOWN COUNT= 16 (8SEC)
        RETI

QCS04:  LOAD IX= QCS05:
        LOAD (DLYPTR)= (IX)
        SEND OPEN QCSOL VALVE
        ENABLE CTC1 TO INTERRUPT
        LOAD DOWN COUNT= 06 (3SEC)
        RETI

QCS05:  LOAD IX= QCS06:
        LOAD (DLYPTR)= (IX)
        SEND OFF ALL VALVES
        CALL RDYPH:
        RETI
```

QC SEQUENCE - (CONT)

```
QCS06:  LOAD IX= QCS07:
        LOAD (DLYPTR)= (IX)
        CALL FIXQC:
        SEND OPEN DRAIN VALVE
        ENABLE CTC1 TO INTERRUPT
        LOAD DOWN COUNT= 24 (12SEC)
        RETI

QCS07:  LOAD IX= QCS08:
        LOAD (DLYPTR)= (IX)
        SEND OPEN KCL VALVE
             CLOSE DRAIN VALVE
        ENABLE CTC1 TO INTERRUPT
        LOAD DOWN COUNT= 06 (3SEC)
        RETI

QCS08:  LOAD IX= QCS09:
        LOAD (DLYPTR)= (IX)
        SEND OFF ALL VALVES
        SET (SEQBSY) BIT 2= 0
        TURN OFF QC SEQ. LED
        RETI

QCS09:  RETI
```

SECTION 15

SOURCE CODE LISTING OF PROGRAM

This section of the manual contains 57 pages of Z-80 microprocessor code. It has been deleted in the interest of saving paper. Copies of the code can be obtained from the author.

SECTION 16

CIRCUIT BOARD SCHEMATICS

A schematic for the special purpose board, also referred to as the interface schematics board, is shown in Figure 16-1. A schematic of the upper chamber wiring is shown in Figure 16-2. Circuit schematics for the purchased Pro-Log boards are shown. Figure 16-3 shows the CPU board. The AC triac board is shown in Figure 16-4 and the keypad board is shown in Figure 16-5.

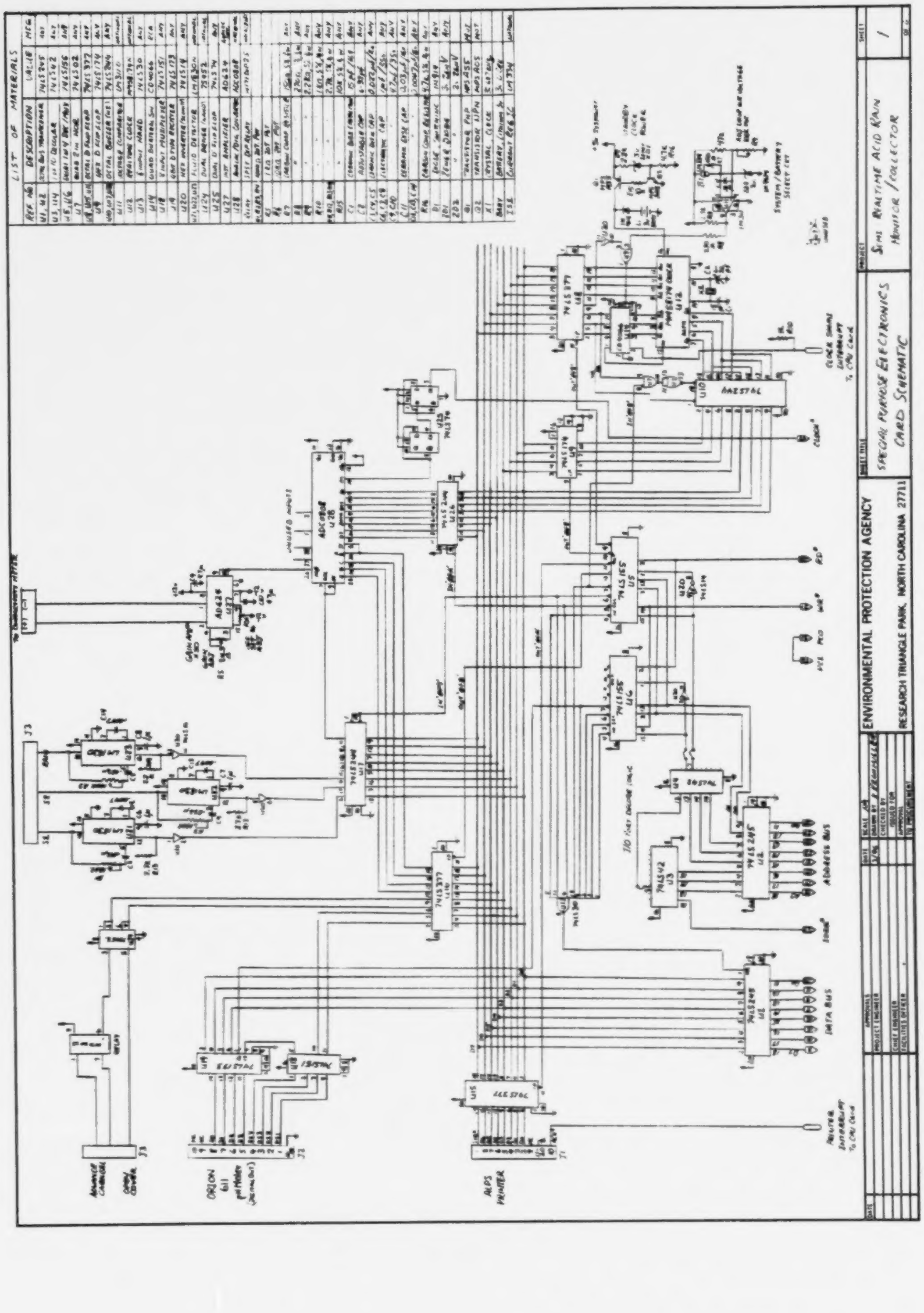

LIST OF MATERIALS
REF. NO.
DESCRIPTION
VALUE
MFG.
ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711
SPECIAL PURPOSE ELECTRONICS CARD SCHEMATIC
SEMI REALTIME ACID RAIN MONITOR / COLLECTOR
SHEET
1
AD624
ADC0808
74LS245
74LS373
74LS377
74LS138
74LS165
DATA BUS
ADDRESS BUS
ALPS PRINTER
ORION 611
CLOCK

Figure 16-1. Special Purpose Board Electronics.

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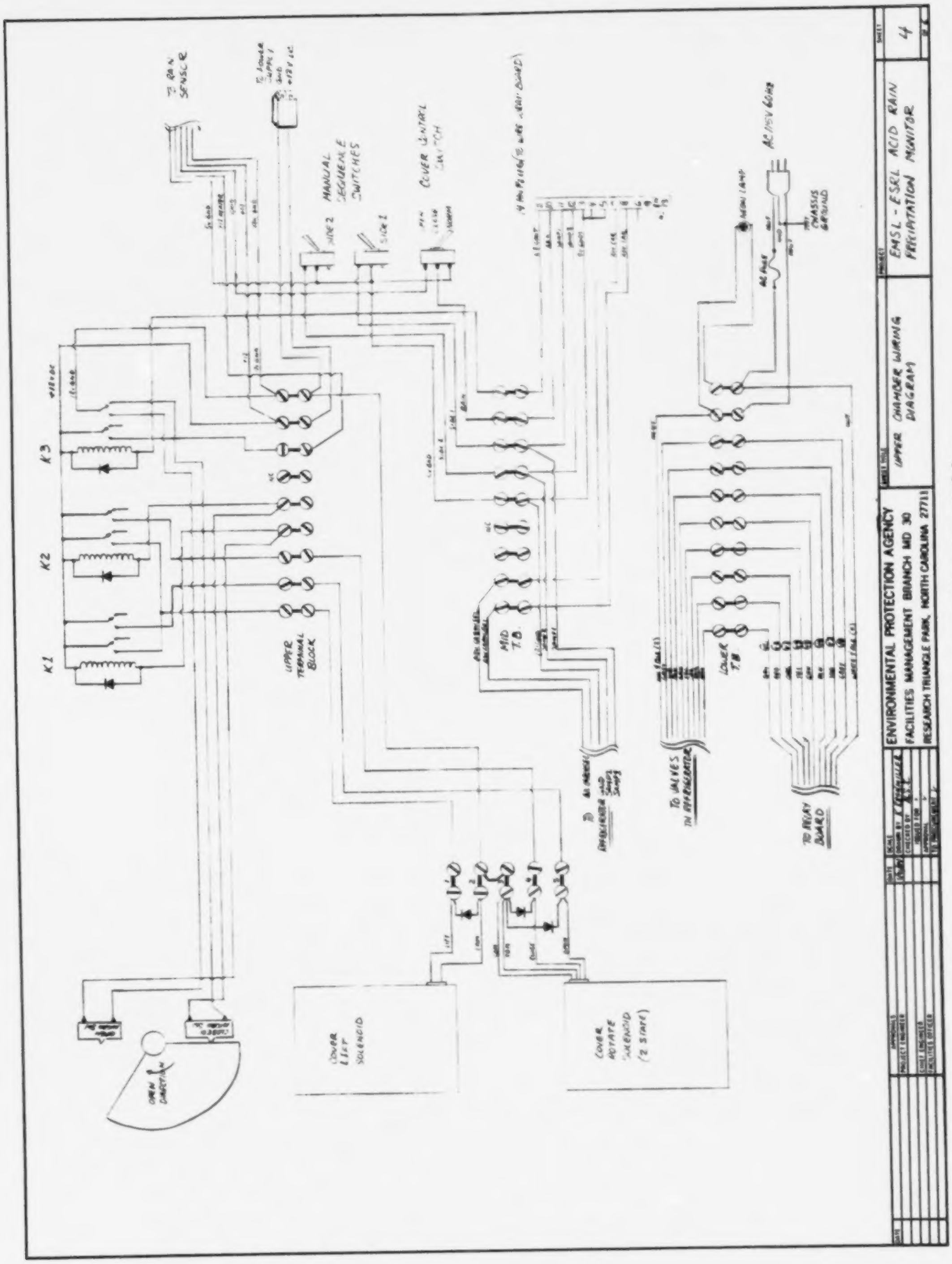
TO RAIN SENSOR
TO POWER SUPPLY
MANUAL SEQUENCE SWITCHES
SIDE 2
SIDE 1
COVER CONTROL SWITCH
K1
K2
K3
UPPER TERMINAL BLOCK
MID T.B.
LOWER T.B.
TO VALVES IN REFRIGERATOR
TO RELAY BOARD
AC 115V 60HZ
CHASSIS GROUND
NEON LAMP
AC FUSE
COVER LIFT SOLENOID
COVER ROTATE SOLENOID (2 STATE)
OPEN DIRECTION
ENVIRONMENTAL PROTECTION AGENCY
FACILITIES MANAGEMENT BRANCH MD 30
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711
UPPER CHAMBER WIRING DIAGRAM
EMSL - ESRL ACID RAIN PRECIPITATION MONITOR
SHEET
4
DATE
SCALE
DRAWN BY
CHECKED BY
APPROVAL
PROJECT ENGINEER
CHIEF ENGINEER
FACILITIES OFFICER

Figure 16-2. Upper Chamber Wiring.

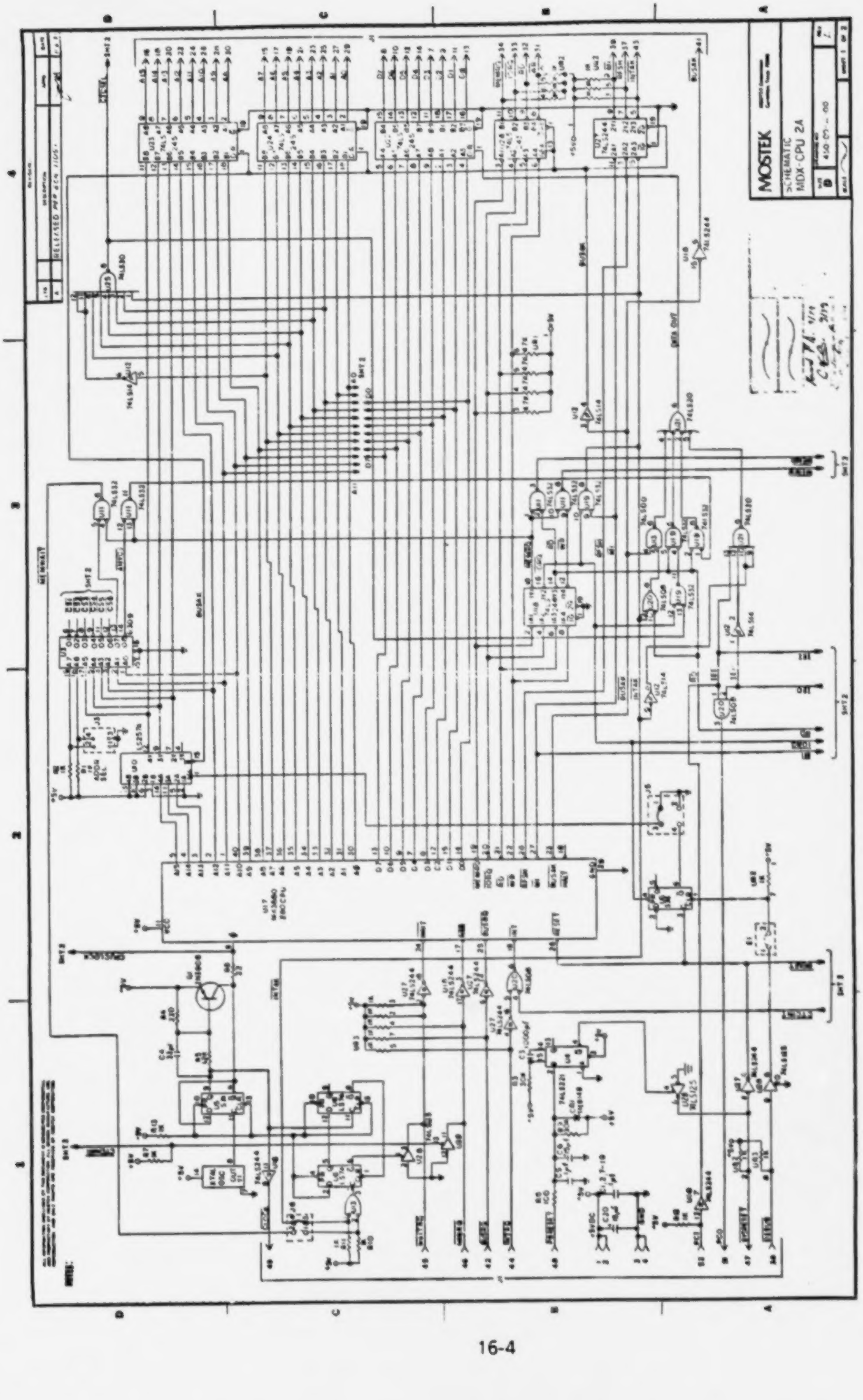
MOSTEK
SCHEMATIC
MDX-CPU 2A
Z80 CPU
SHT 2

Figure 16-3. Circuit Schematics for the Purchased CPU Board.

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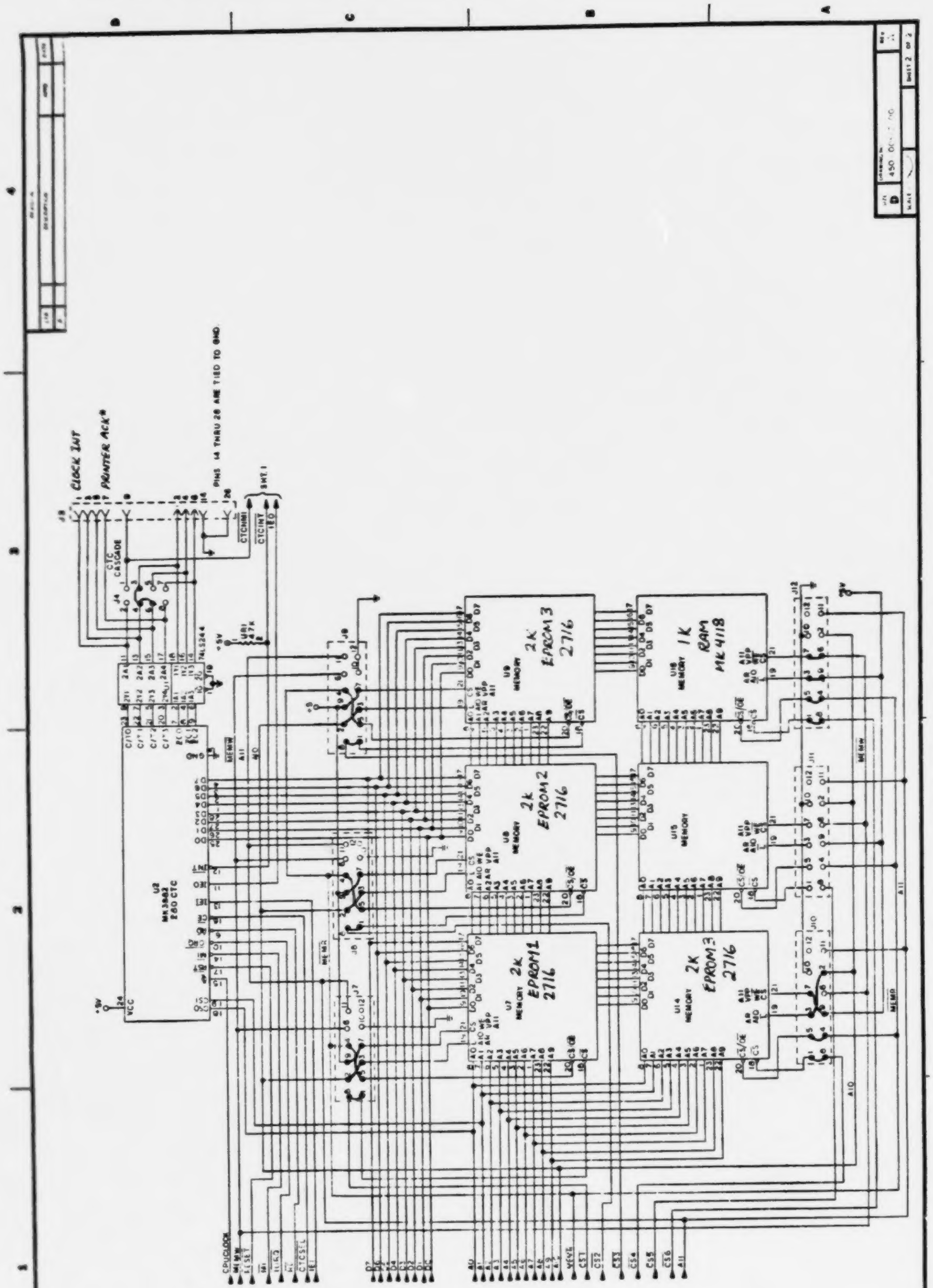

CLOCK INT
PRINTER ACK*
PINS 14 THRU 26 ARE TIED TO GND
CTC CASCADE
74LS244
U2 MK3882 Z80 CTC
2K EPROM 3 2716
1K RAM MK 4118
2K EPROM 2 2716
2K EPROM1 2716
2K EPROM3 2716
SHT 1

Figure 16-3. (continued)

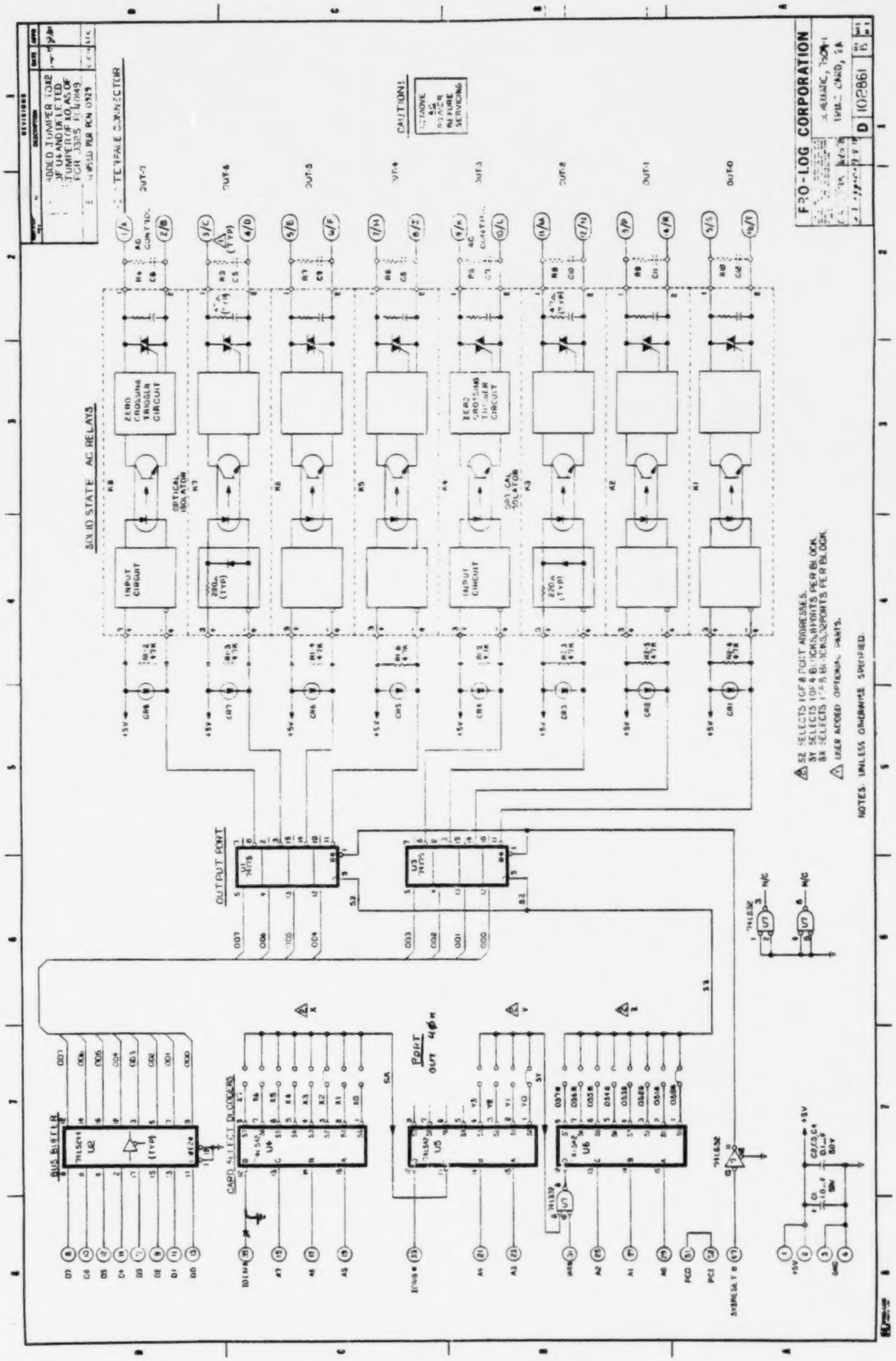

SOLID STATE AC RELAYS
ZERO CROSSING TRIGGER CIRCUIT
INPUT CIRCUIT
OPTICAL ISOLATOR
OUTPUT PORT
BUS BUFFER
CARD SELECT DECODERS
PORT
CAUTION!
REMOVE AC POWER BEFORE SERVICING
FEMALE CONNECTOR
PRO-LOG CORPORATION
OUT-0
OUT-1
OUT-2
OUT-3
OUT-4
OUT-5
OUT-6
OUT-7
U1
U2
U3
U4
U5
U6
U7
+5V
S2 SELECTS 1 OF 8 PORT ADDRESSES.
SY SELECTS 1 OF 4 BLOCKS, 8 PORTS PER BLOCK.
SX SELECTS 1 OF 8 BLOCKS, 32 PORTS PER BLOCK.
USER ADDED OPTIONAL PARTS.
NOTES: UNLESS OTHERWISE SPECIFIED.

Figure 16-4. Circuit Schematic for the AC Triac Board.

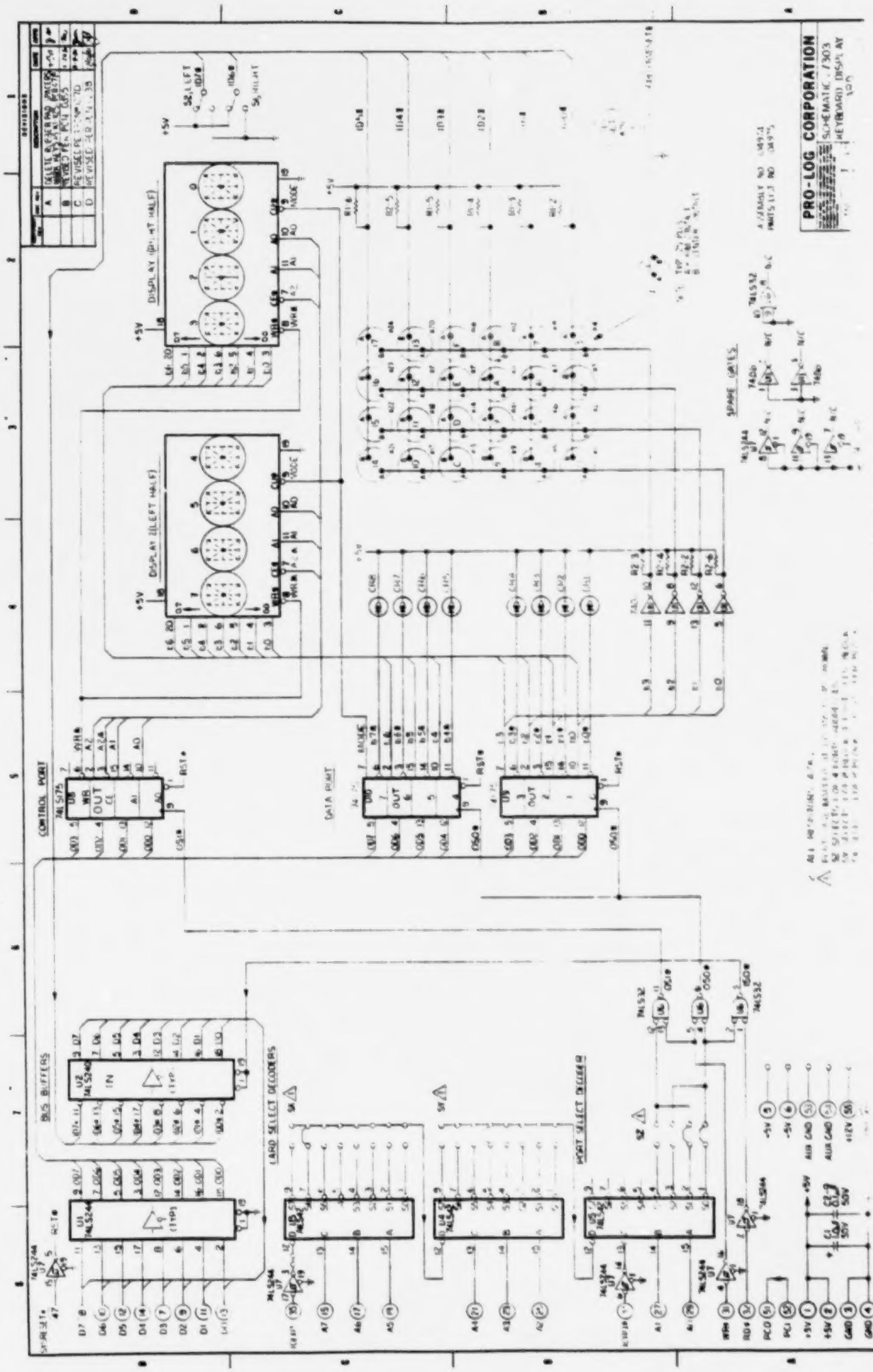

PRO-LOG CORPORATION
SCHEMATIC, 7303
KEYBOARD DISPLAY
DISPLAY (RIGHT HALF)
DISPLAY (LEFT HALF)
CONTROL PORT
DATA PORT
BUS BUFFERS
CARD SELECT DECODERS
PORT SELECT DECODER
SPARE GATES
74LS175
74LS244
74LS32
+5V

Figure 16-5. Circuit Schematic for the Keypad Board.

Reproduced from best available copy.

SECTION 17

COMPREHENSIVE PARTS AND COMPONENTS LISTS

TABLE 17-1. COMPREHENSIVE PARTS LIST

Component Name	Manufacturer	Model No.	Comments
Electronics Power Supply	Pro-Log, Inc.	M 281-1	+ 5 V @ 10 A/ ± 12 V @ 1A
Circuit Board Card Cage	Pro-Log, Inc.	BR 08-H	8 slot, bussed
CPU Card: Z80 u-P	Mostek, Inc.	MDX-CPU2	needs modification
AC Relay Card	Pro-Log, Inc.	7504	needs modification
Keyboard/Display Card	Pro-Log, Inc.	7303	needs modification
Special Purpose Card*	Pro-Log, Inc.	7903	bare board for component
Printer, 20 columns	ALPS, Inc.	ASG 1100	
Digital pH Meter	Orion Research	611	
pH Electrode	Orion Research	916200	modify (extend) cable
Sample Carousel	Eldex Labs.	Universal	needs modification
Vial Carousel	Eldex Labs.	URIA-50 RIA	50-position collector
Refrigerator	J.C. Penney	867-3105-10-20	needs modification
Temperature Controller	R.F.L. Indus.	TC-40	needs modification
Pinch Valves (2-way)	Angar	373-115-10-10	
Pinch Valves (3-way)	Angar	401-NC-115-10-10	
Misc. Teflon tubing	any		
Misc. Teflon fittings	any		
Teflon Sample Accumulators	Fischer Scientific	10-437-25A	needs modification
Cover Lift Mechanism	U. of Minnesota		needs modification
Lower Chamber Enclosure	Machine Shop fab.		
Rain Sample Vials	Fisher Scientific	05-538-55A	
Rain Sensor (detector)	AeroChem Metrics		needs modification
Conductivity Meter	Amber Science	1052	
Conductivity Cells(s)	Amber Science	1115	

* Components listed in Table 17-2.

TABLE 17-2. SPECIAL PURPOSE CARD COMPONENTS

Description	Type or Value	Manufactuer	Comments
Integrated Circuit	LM 1830 N	National Semi.	3 required
Integrated Circuit	LM 311 N	National Semi.	1 each
Integrated Circuit	LM 75452 N	National Semi.	2 each
Integrated Circuit	MM 58174 N	National Semi.	1 each
Integrated Circuit	74 LS 14 N	National Semi.	1 each
Integrated Circuit	74 LS 123 N	National Semi.	1 each
Integrated Circuit	74 LS 151 N	National Semi.	1 each
Integrated Circuit	74 LS 173 N	National Semi.	1 each
Integrated Circuit	CD 4016 C	National Semi.	1 each
Transistor, NPN Si	2N 2222	National Semi.	2 each
Diode, gen. purpose	1N 914A	National Semi.	5 each
Voltage Regulator	LM 329	National Semi.	1 each
Relay, n.o.	W171DIP-2	Magnecraft	1 each
Battery, Li button	P-139	Digi-Key	1 each
Clock Crystal	KF-38G	Digi-Key	1 each
Variable resistor	10 K-ohm	any	1 each
Variable resistor	100 K-ohm	any	3 each
Resistor, 5%, $\frac{1}{4}$ W	680 ohm	any	3 each
Resistor, 5%, $\frac{1}{4}$ W	2.7 K-ohm	any	8 each
Resistor, 5%, $\frac{1}{4}$ W	6.8 K-ohm	any	1 each
Resistor, 5%, $\frac{1}{4}$ W	100 K-ohm	any	2 each
Resistor, 5%, $\frac{1}{4}$ W	220 K-ohm	any	2 each
Capacitor, Electrolytic	22 μF, 16 V DC	any	2 each
Capacitor, Electrolytic	10 μF, 16 V DC	any	1 each
Capacitor, Electrolytic	4.7 μF, 16 V DC	any	3 each
Capacitor, ceramic disk	0.01 μF, 10 V DC	any	1 each
Capacitor, ceramic disk	0.033 μF, 10 V DC	any	3 each
Capacitor, ceramic disk	0.1 μF, 10 V DC	any	1 each
Capacitor, ceramic disk	0.47 μF, 10 V DC	any	3 each

TABLE 17-3. MISCELLANEOUS COMPONENTS

Description	Type or Value	Manufactuer	Comments
IC Socket: 8-pin DIP	ICO 308 WGG	Samtek	3 each
IC Socket: 14-pin DIP	ICO 314 WGG	Samtek	9 each
IC Socket: 16-pin DIP	ICO 316 WGG	Samtek	4 each
Comp. Socket: 16-pos DIP	AP 316 AG	Samtek	5 each
Cable Socket: 26-pos DIL	FC-140-26	Alpha	2 each
Relay, 2 form C	K10P11A15-12 V DC	Potter & Brumfield	3 each
Relay Socket	27E487	Potter & Brumfield	3 each
Terminal Barrier Strip	76010	V-Beau	4 each
Switch, n.o. mom	7108 SYZQ	C & K Switch	2 each
Switch, spst	7101 SYZQ	C & K Switch	1 each
Switch, on-off-on	7103 SYZQ	C & K Switch	1 each
AC line cord	--	any	1 each
Fuse holder and fuse	322012	Littelfuse	1 each
Neon Indicator	6063-000-534	Littelfuse	1 each
Audio Buzzer	PKB8-4AO	MuRata	1 each
AC Power Strip	1301-XS	SPC Technology	1 each
AC Input Connector	5278	Hubbell	1 each
AC Fans	WX3H1-028860	Rotron	3 each
Fan Cable	428056	Rotron	3 each

SECTION 18

MODIFICATIONS TO PURCHASED SUBASSEMBLIES

18.1 PRO-LOG CURCUIT BOARD CARD CAGE

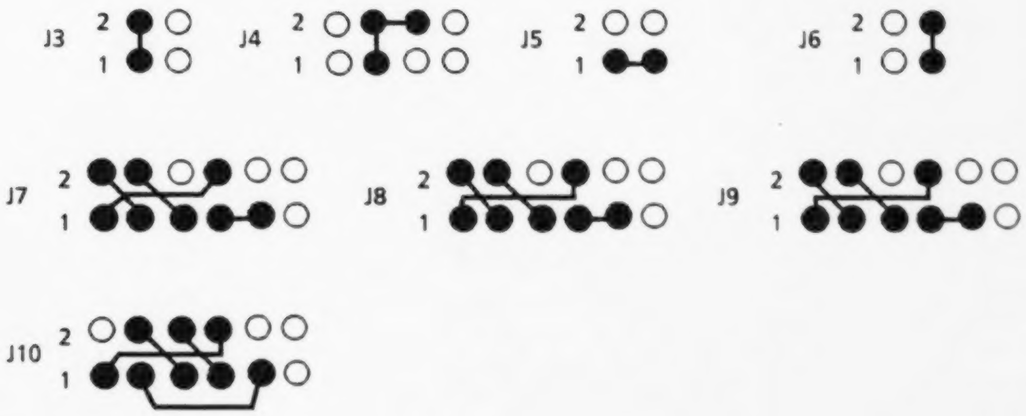
The card cage as supplied from the vendor has no cable connected to the power supply trace for supplying + 12 V and 12 V ground to terminal strip. To add this cable it is necessary to prepare a two-conductor cable (18 gauge stranded, 3 ft) with terminal lugs on the wires at one end, and solder the two wires at the other end to the holes provided on the card cage circuit board.

18.2 MOSTEK Z80 CPU CIRCUIT CARD

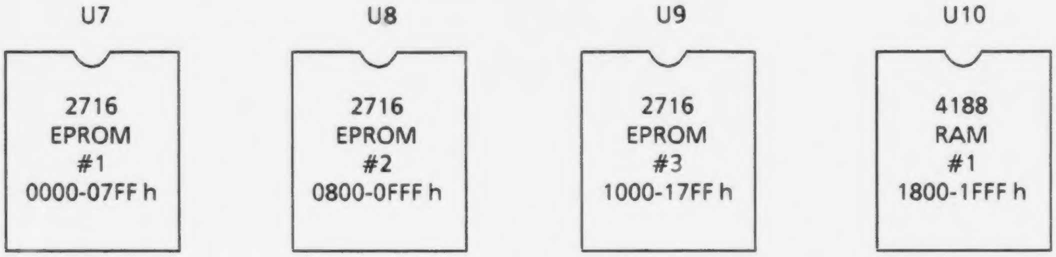
This card as supplied from the vendor requires the addition of certain jumpers to enable operation. In addition, the program EPROMS and RAM chips will have to be inserted in their correct sockets.

Because this board contains MOS integrated circuits, be sure to follow standard safety precautions of grounding the surface the board is on, and grounding the technician who performs these modifications.

Step 1. Make the following jumpers (either wire wrap or jumpers):



Step 2. Insert the program EPROMS and RAM chip as shown below:



18.3 AC RELAY CIRCUIT CARD

This card provides a good way to connect the STD bus pin (IOEXP*) to ground so the port decoding is enabled correctly. Solder a short insulated wire from U4 pin 8 to pin 12.

18.4 PRO-LOG KEYBOARD/DISPLAY CIRCUIT CARD

This board requires a modification to the port decoding jumper SY. It also requires a soldered jumper to disable STD bus pin 35 (IOEXP*).

Step 1. Unsolder the jumper at SY pin 5-12 as obtained from the vendor.
Solder a jumper between SY pins 1-2 (most bottom locations)
(SY located to the right of U4)

Step 2. Solder an insulated wire from IC U3 pin to pin 12.

18.5 ELDEX SAMPLE CAROUSEL

The carousel as purchased from the vendor requires an additional connection of wires in parallel to the RESET/ADVANCE push-button switch on the front panel. These wires should be connected to panel connectors to which the wires from the electronic module can also be attached.

18.6 J.C. PENNEY REFRIGERATOR

The refrigerator used in the monitor requires extensive modifications. Electrically, the temperature control circuit is replaced with one that has more precision, which also requires modification. Physically, the refrigerator must be modified to accept the carousel, which is otherwise too large to fit inside, along with the sample accumulators, the pH chamber, and the terminal strip for the valve control wiring. Follow the steps below to modify the refrigerator.

Step 1. With power to the refrigerator off, remove the plastic cover over the wiring block (rear of unit near the compressor).

Step 2. Refer to the drawing in Figure 18-1 to wire the refrigerator as shown.

18.7 SAMPLE ACCUMULATOR

The Teflon separatory funnels as purchased need to be modified for use in the sampler. Remove and discard the stopcocks. Then thread the hole to accept the solenoid valve fitting. Drill the caps to allow the tubing and sample probes to pass through them. Drill the side walls to accept a Teflon fitting, which provides the excess rain ports. Modify the pH chamber separatory funnel in a similar fashion, except the holes should be drilled into the side to provide an entrance for the rain, QC solution, and distilled water. The cap for the pH chamber should be drilled to accept the pH electrode and provide a tight fit so it can be firmly located.

18.8 AEROCHEM METRICS RAIN DETECTGOR

This detector as purchased requires modification to work correctly in the sampler. Change the original wiring so that the grids are isolated from the rest of the circuitry to keep the + 5 V ground isolated from the + 12 V ground. Follow the details shown in the drawing in Figure 18-2, which is also included in the document set.

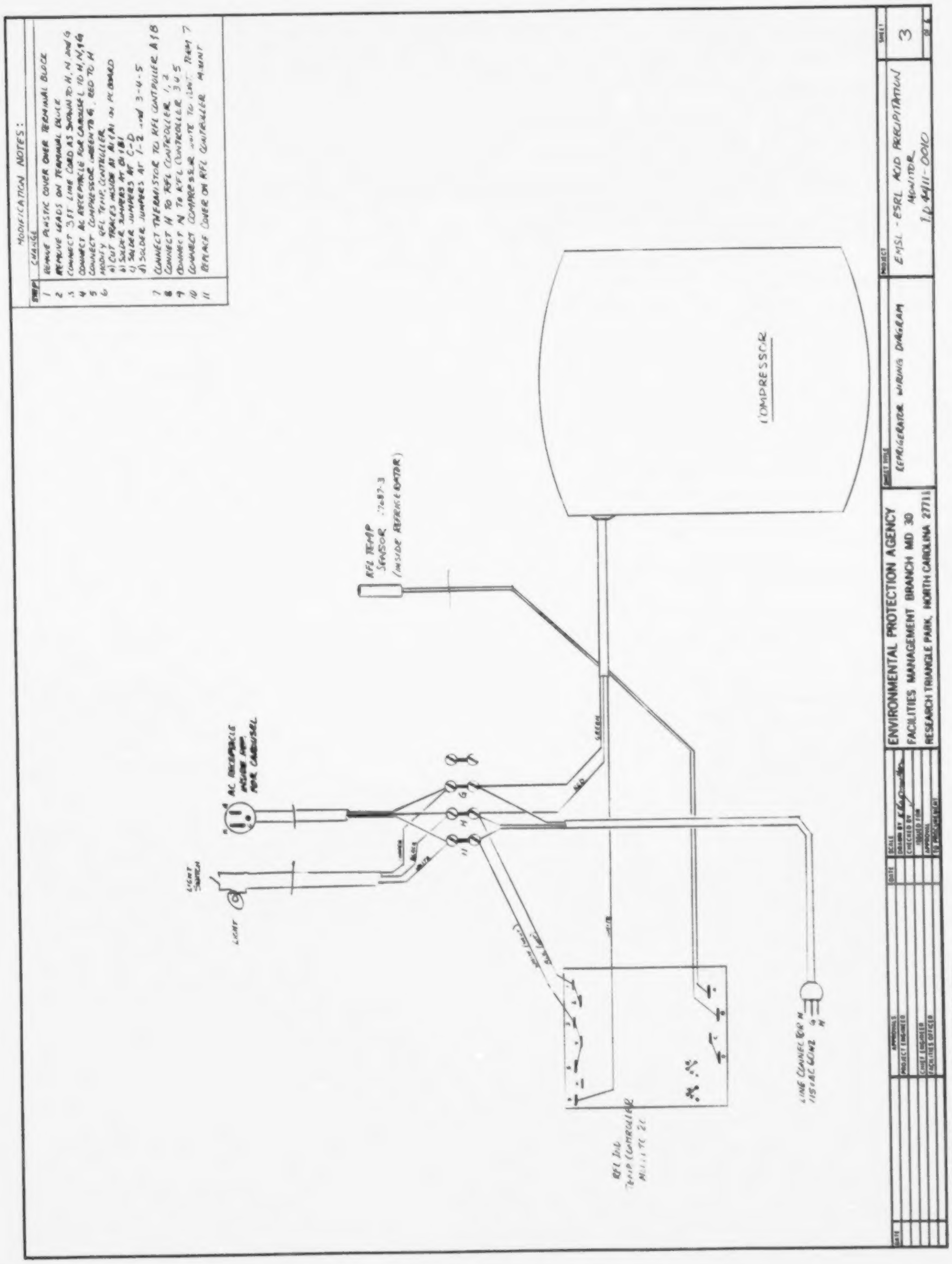

MODIFICATION NOTES:
STEP CHANGE
1 REMOVE PLASTIC COVER OVER TERMINAL BLOCK
2 REMOVE LEADS ON TERMINAL BLOCK
3 CONNECT 3FT LINE CORD AS SHOWN TO H, N AND G
4 CONNECT AC RECEPTACLE FOR CAROUSEL TO H, N, AND G
5 CONNECT COMPRESSOR GREEN TO G, RED TO H
6 MODIFY RFL TEMP. CONTROLLER
a) CUT TRACES INSIDE AT A1(A) ON PC BOARD
b) SOLDER JUMPERS AT B1 1B1
c) SOLDER JUMPERS AT C-D
d) SOLDER JUMPERS AT 1-2 and 3-4-5
7 CONNECT THERMISTOR TO RFL CONTROLLER A1B
8 CONNECT H TO RFL CONTROLLER 1, 3
9 CONNECT N TO RFL CONTROLLER 3 4 5
10 CONNECT COMPRESSOR WHITE TO CONT. TERM 7
11 REPLACE COVER ON RFL CONTROLLER MAINT
COMPRESSOR
RFL TEMP SENSOR 3
(INSIDE REFRIGERATOR)
AC RECEPTACLE INSIDE REFR. FOR CAROUSEL
LIGHT
LIGHT SWITCH
H N G
RED
GREEN
RFL DIG TEMP CONTROLLER
LINE CONNECTOR H 115 VAC 60 Hz
ENVIRONMENTAL PROTECTION AGENCY
FACILITIES MANAGEMENT BRANCH MD 30
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711
REFRIGERATOR WIRING DIAGRAM
EMSL-ESRL ACID PRECIPITATION MONITOR
SHEET 3

Figure 18-1. J.C. Penney Refrigerator Wiring Diagram.

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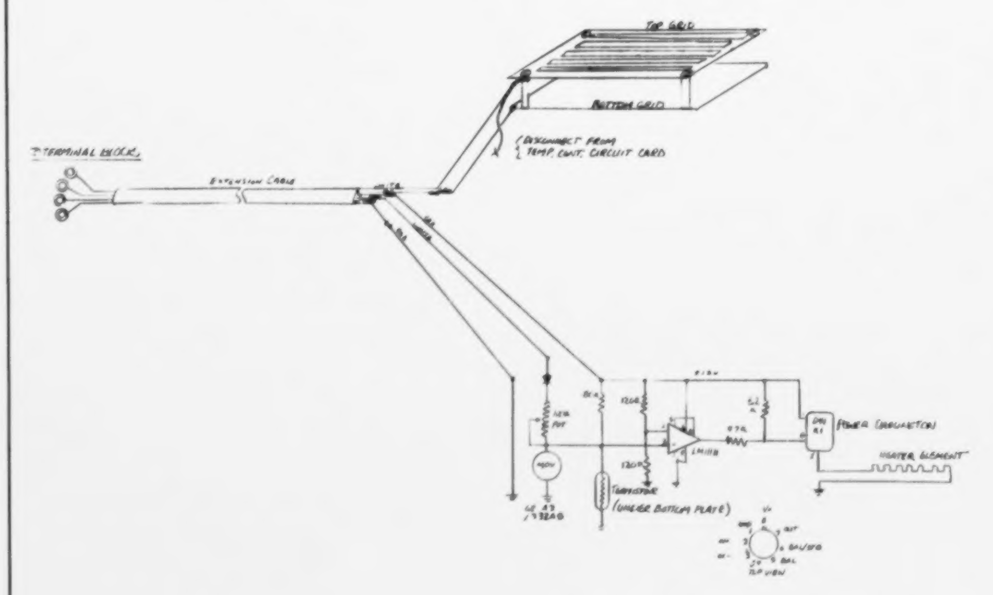
MODIFICATIONS	
STEP	CHANGE
1	OPEN CASE TO GAIN ACCESS TO INSIDES
2	REMOVE BLACK WIRE FROM TOP GRID TO CONTROLLER CIRCUIT BOARD.
3	SOLDER WHITE WIRE OF EXTENSION CABLE TO TOP PLATE POST
4	SOLDER BLACK WIRE OF NEW CABLE TO BOTTOM PLATE GREEN WIRE
5	SOLDER RED TO RED
6	SOLDER ORANGE TO WHITE
7	SOLDER GREEN TO BLACK
8	RE-ASSEMBLE UNIT & MOUNT


TOP GRID
BOTTOM GRID
(DISCONNECT FROM
TEMP. CONT. CIRCUIT CARD)
TERMINAL BLOCK
EXTENSION CABLE
10K POT
120K
120K
6.2K
LM311B
POWER REGULATOR
HEATER ELEMENT
THERMISTOR
(UNDER BOTTOM PLATE)
TOP VIEW
OUT
BAL

DATE	APPROVALS	DATE	SCALE	ENVIRONMENTAL PROTECTION AGENCY	SHEET TITLE
	PROJECT ENGINEER		DRAWN BY Chamberlain	FACILITIES MANAGEMENT BRANCH MD 30	RAIN SENSOR ELECTRICAL MODIFICATION
	CHIEF ENGINEER		CHECKED BY ✓	RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711	(STANDARD AEROCHEM METRICS SENSOR)
	FACILITIES OFFICER		ISSUED FOR APPROVAL TO PROCUREMENT		

PROJECT: EMSL - ESRL ACID PRECIPITATION MONITOR TD 4411 - 0010

SHEET 2 OF 6

Figure 18-2. Aerochem Metrics Rain Detector Electrical Modification.

SECTION 19

COMPONENT VENDORS' ADDRESSES

Pro-Log, Inc., 2411 Garden Rd., Monterey, CA 93940 (408) 538-9570

Mostek Corp., 1215 W. Crosby Rd., Carrollton, TX 75006 (214) 242-0444

ALPS Printer, NEEDS 25 Green St., Waltham, MA 02154 (617) 647-5709

Orion Research, 840 Memorial Dr., Cambridge, MA 02139 (617) 864-5400

Eldex Labs, Inc., 831 Bransten Rd., San Carlos, CA 94070 (415) 592-9270

J.C. Penney, 1301 Avenue of the Americas, New York, NY 10019

RFL Industries, Inc., Boonton, NJ 07005 (201) 334-3100

Mace Corp., 2413 Lee Ave., South , El Monte, CA 91733 (213) 443-3104

Fisher Scientific, 3315 Winton Rd., Raleigh, NC 27604 (919) 876-2351

Aerochem Metrics, P.O. Box 69, Nobleton, FL 33554 (904) 793-8000

Arrow Electronics, Raleigh, NC (919) 876-3132, National Semiconductor, ICs

Digi-Key, Hwy 32, South, P.O. Box 677, Thief River Falls, MT (800) 346-5144

Newark Electronics, 3301 Womans Club Dr., Raleigh, NC (919) 781-7677, Miscellaneous Electronics

Angar Valve: Purser, London, & Edwards, P.O. Box 11996, Charlotte, NC 28209 (704) 366-9222

Amber Science, 277 Blair Blvd., Eugene, OR 97402 (503) 345-6877